S. A. E. JOURNAL

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Edward P. Warner, *President* Coker F. Clarkson, *Secretary* C. B. Whittelsey, Jr., *Treasurer*

Vol. XXVI April, 1930 No. 4

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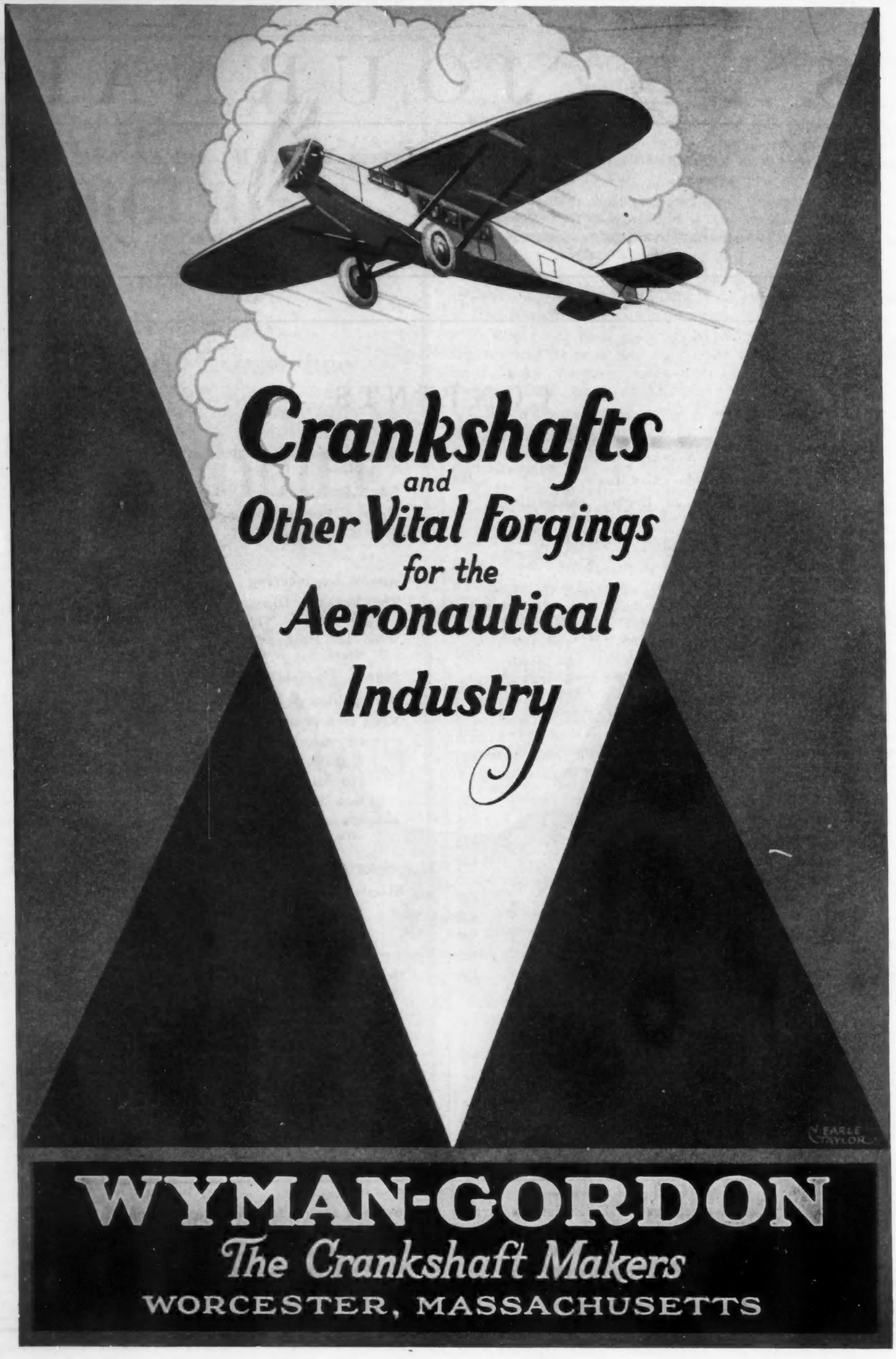
The purpose of meetings of the Society is largely to provide a forum for the presentation of straightforward and frank discussion. Discussion of this kind is encouraged. However, owing to the nature of the Society as an organization, it cannot be responsible for statements or opinions advanced in papers or in discussions at its meetings. The Constitution of the Society has long contained a provision to this effect.


Crankshafts
and
Other Vital Forgings
for the
Aeronautical
Industry
EARLE TAYLOR
WYMAN-GORDON
The Crankshaft Makers
WORCESTER, MASSACHUSETTS

S. A. E. JOURNAL

Vol. XXVI April, 1930 No. 4

Detroit Aeronautic-Meeting Attractions

Three Days in Aircraft Show Week To Be Devoted to Technical Sessions, Glider Flights and Unique Inspection Trip

THE All-American Aircraft Show, to be held in Detroit April 5 to 13, will provide the setting for the Detroit Aeronautic Meeting of the Society, which is scheduled to be held in the Book-Cadillac Hotel April 8, 9 and 10.

Three sessions devoted to technical papers, a dinner sponsored by the Aeronautic Division of the Detroit Section of the S.A.E., a glider demonstration under the auspices of the National Glider Association, and a trip to the Ford Airport, Ford airplane factory and Ford Museum and Antique Village will comprise the meeting activities.

Tuesday morning, April 8, will be devoted to aircraft engines, with two papers of unusual interest. Dr. S. A. Moss, of the Thompson Research Laboratory of the General Electric Co., will speak on Geared Centrifugal Superchargers for Airplane Engines. Interesting prepared discussion of this paper will be submitted by Arthur Nutt, chief engineer of the Curtiss Aeroplane & Motor Co., and other well-known engine designers.

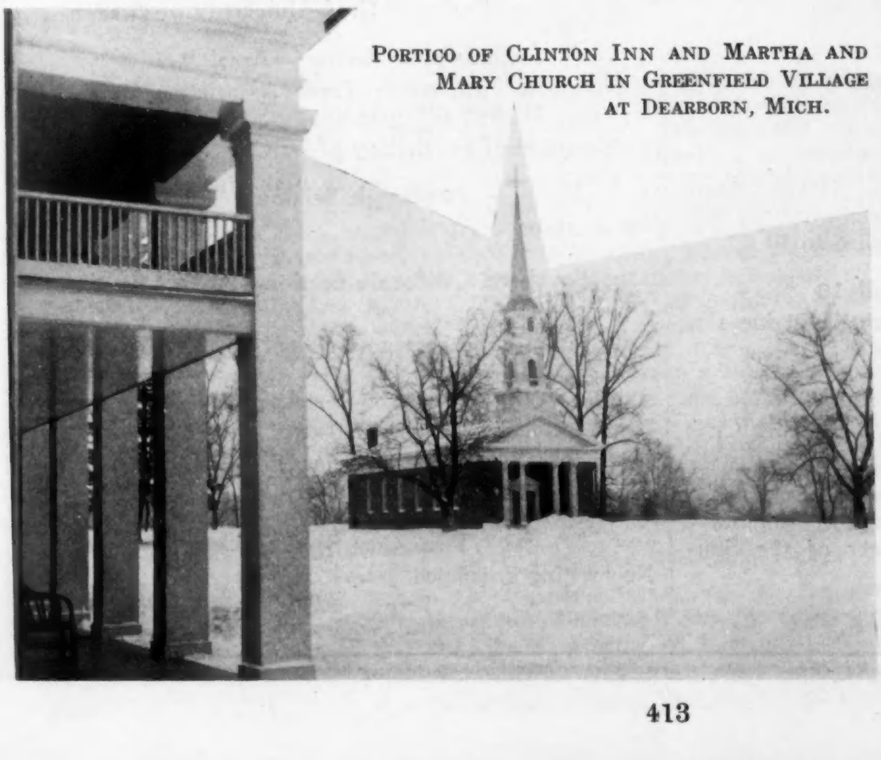
Aircraft-engine designers generally will be interested in the paper prepared by Wesley M. Smith and E. N. Lott, of the National Air Transport, on Aircraft-Engine Requirements from an Operator's Viewpoint. It is anticipated that Mr. Smith, in the presentation of this paper, will outline the shortcomings of present engines and give some idea of what must ultimately be developed in the line of aircraft engines if economical operation of commercial air-lines is to be assured. Problems of performance, servicing and engine life and cost must be solved before the ideal engine for this service is developed.

Feature of the Aircraft Banquet

The Aircraft Banquet, to be held Tuesday evening in the grand ball room of the Book-Cadillac by the Aeronautic Division of the Detroit Section, will bring together the foremost engineers of the industry to hear Capt. L. M. Woolson discuss the construction details and performance of the Packard Diesel Aircraft-Engine, which will be exhibited to the public for the first time at the All-American Aircraft Show. The great amount of time and money spent in the perfecting of this unique aircraft engine has whetted the interest of the entire Country, and there is no doubt that Captain Woolson will find as great an interest in his engine as has been evinced in anything in the industry for some time.

Wednesday morning, April 9, will be devoted to aircraft. Edward P. Warner, President of the Society and editor of *Aviation*, whose subject is, What Is Lightness Worth in an Airplane, will discuss the economics of weight saving.

Since the award of the $100,000 prize in the Safe Airplane Competition by the Guggenheim Fund for the Promotion of Aeronautics, data have been issued from time to time regarding the Curtiss Tanager, the performance of which in competition with numerous contestants secured for the builders the much coveted prize. The Society is particularly fortunate that T. P. Wright, chief engineer of the Curtiss Aeroplane & Motor Co., will discuss at this session the details of design and performance of this remarkable airplane.



PORTICO OF CLINTON INN AND MARTHA AND MARY CHURCH IN GREENFIELD VILLAGE AT DEARBORN, MICH.

Glider Demonstrations Wednesday Afternoon

The afternoon will be given over to gliders, which have in the last year attained considerable prominence and on which many companies are devoting a great deal of work. William Perfield, an engineer from the Stout Engineering Laboratories, will present a paper at 2 o'clock on the Principles of Glider Design. Immediately following this paper, all guests will leave the Book-Cadillac Hotel at 3 o'clock, in buses provided for the purpose, for the Detroit Municipal Airport, where a demonstration of glider flying will be pro-

Meetings Calendar

National Meetings of the Society

Detroit Aeronautic—April 8 to 10
Book-Cadillac Hotel

Metropolitan Aeronautic—May 6 and 7
New York City

Summer Meeting—May 25 to 29
French Lick Springs

Probable West Coast Transportation—July 1-2
San Francisco

Chicago Aeronautic—August 26 to 28
(In conjunction with National Air Races)

Production—October 8 and 9
Book-Cadillac Hotel, Detroit

Transportation—October 22 to 24
Pittsburgh

April Section Meetings

Baltimore Section—April 30

Aeronautic Meeting—Inspection trip to aircraft plants in the vicinity, dinner in the evening, and talks by prominent aircraft manufacturers

Buffalo Section—April 1

Hotel Statler

Fuel-Moving Systems—E. W. Dilg, Chief Engineer, Evans Appliance Co.

Canadian Section—April 16

Toronto

Sticking Pins through Opinions—John Warner

Chicago Section—April 8

Motorcoach and Motor-Truck Transportation

Cleveland Section—April 14

Hotel Cleveland; Dinner

Analysis and Study of Valve Mechanism—Ferdinand Jehle

Detroit Section—April 8

Book-Cadillac Hotel

Aircraft Banquet—April 8, 6.30 p.m.

The Section will collaborate in the National Aeronautic Meeting of the Society during the All-American Aircraft Show, April 8 to 10

Indiana Section—April 10

Round Engines—E. S. Hall, Michell Engine Co., Los Angeles

Metropolitan Section—April 2

A.W.A. Building, 357 W. 57th St., New York City; Dinner, 6.30 p.m.

High-Speed Developments Covering Design of Silver Bullet, Aircraft and Diesel Engines—Louis Coatalen, Chief Engineer of the Sunbeam Motor Car Co.

Personal Story of Speed Runs at Daytona Beach—Kaye Don

Milwaukee Section—April 4

3.00 p.m.—Inspection of A. O. Smith Automatic Frame-Plant

6.30 p.m.—Dinner; Milwaukee Athletic Club

8.00 p.m.—Paper on Electric Welding—T. McLean Jasper, Director of Research, A. O. Smith Corp.

New England Section—April (?)

Lubrication—By a representative of the Vacuum Oil Co.

Northwest Section—April 4

Bergonian Hotel, Seattle, Wash.

Bearing Metals and Alloys—C. C. Finn

Oregon Section—April 11

Multnomah Hotel, Portland

Carburetion—Professor Graf, University of Oregon

Philadelphia Section—April 9

Philadelphia Automobile Trade Association Building; Dinner, 6.30 p.m.

Relationship of Psychology to Driving

Pittsburgh Section

No meeting in April

Southern California Section—April 11

Dinner, 6.15 p.m.

Lubrication—Speakers not selected up to March 20

Syracuse Section—April 15

Hotel Syracuse; Dinner, 6.30 p.m.

Address by Edward P. Warner, Editor of *Aviation* and President of the Society

Twin City Section

No meeting scheduled

vided by the National Glider Association.

Shock-cord-launched flights and automobile-towed flights will comprise the largest part of the demonstration. Also it may be possible, dependent somewhat on the amount of equipment obtainable, to afford members of the Society who desire to do so an opportunity to make short shock-cord-launched flights.

Visit to Ford Airport and Village

On Thursday, April 10, through special arrangement, members and guests of the Society will be given an opportunity to visit the Ford Airport, airplane factory, museum and antique village. Buses will leave the boulevard entrance of the Book-Cadillac promptly at 10 a. m., and luncheon will be served at the airport. The extraordinary privilege accorded by permission to visit the village can be appreciated from the following description:

The Edison Institute of Technology at Dearborn is intended by Henry Ford to conserve for the coming generation of young Americans the inspiration of his friend Thomas A. Edison. It occupies 125 acres, with the main museum building and the historical village of Greenfield. One section of the village contains the very buildings used by Mr. Edison at Menlo Park, N. J., during the period in which he developed the phonograph and incandescent light, together with the system for its distribution, while in other parts of the village is portrayed the handicraft arts of the past and the major steps in the development of American architecture.

The museum is devoted chiefly to industry and science. Agriculture, manufacturing, mining, communication, transportation, power and the domestic arts, customs and crafts form the main divisions. The museum thus becomes the textbook of the students, where they will study not only the industrial arts in which they are particularly interested but also the effect of each industrial era on the public and private life of the people.

The Ford collections of Americana have been accumulating for many years and are probably the largest in the world. Masters of the ceramic and cabinetmakers' arts are well represented, as are also the ordinary itinerant craftsman. A great variety of every type of household utensil has been gathered, ranging from the earliest Colonial to the late Empire and Victorian periods.

The machine-tool and tool section is particularly complete, as are the power groups. In some instances Mr. Ford has brought from Europe the earlier beginnings of the development, as, for example, the textile industry, steam engine, Diesel engine and many machine-tools. Savery, Newcomen and Watt engines have been secured, as have also an Otto and Langlen atmospheric gas-engine. A replica of the Rocket heads the locomotive group.

As far as possible, the exhibits with moving parts will operate by the touch of a button. As students of the Institute will be constantly using many of the exhibits as part of their instruction, visitors will be able to gain a more realistic impression and understanding of the principles of the object, in addition to a knowledge of its romantic history. The historical collections will be housed in a one-story building 450 x 810 ft., of construction similar to that of the Ford engineering laboratory, and which has columns spaced 40 by 43 ft., through which heating and ventilation are arranged.

A replica of Independence Hall in Philadelphia, flanked by a series of connected buildings, forms the front of the museum. These are joined by five arcades to the exhibit building in the rear. In the buildings flanking Independence Hall are the administrative offices, class rooms, research shops, libraries and an auditorium having a seating capacity of 1500.

Layout of Greenfield Village

Greenfield was named for the birthplace of Henry Ford. It follows the general scheme of a colonial village, with the public buildings arranged around a common or green. At one end facing the west is a typical colonial church built of bricks from Mrs. Ford's girlhood home. The doors of her home are worked into the entrance doors of the church.

Around the sides of the common are the old inn, the old red-brick schoolhouse which Mr. Ford attended, a courthouse in which Abraham Lincoln practised law, a typical town hall, country store and jewelry shop. On a side street near by, opposite the post office dating back to 1803, is an old tintype studio. Next to this is the toll-house cobbler's shop mentioned in John G. Whittier's poem, The Countess. The old brick railroad station of Smiths Creek, Mich., at which Edison when a boy was ejected from a train for setting fire to the baggage car while experimenting with chemicals serves as the village depot. A New England machine-shop has been erected, and also a foundry of the 1860 period. No old American village was complete without mills, so there are two here, a grist mill and a circular-saw mill, both approximately 100 years old. An up-and-down saw mill is to be added, and a glass plant modeled after the Sandwich Glass Works. Mr. Ford has the original formula book and the steam engine which operated that industry.

FORD HISTORICAL VILLAGE TO BE VISITED BY MEMBERS ATTENDING THE AERONAUTIC MEETING
Structures, Left to Right—Plymouth House, Toll-House Shoe-Shop, Post Office, Tintype Studio and Blacksmith Shop

Industries in Actual Operation

The industries are represented by actual operations. For example, students will learn how flour was milled on the old burr stones by actually doing it themselves, and the commodity thus produced will be sold to the visitors. The grist mill of the village has been in operation since last October, and the Ford cafeteria at the Dearborn laboratory. Students of shoemaking will make, as Whittier did, Ladies Slippers in the toll-house shoe-shop. The post-office is now a recognized Government branch station, where 10,000 cards have been mailed with the Greenfield cancellation postmark since October, 1929. The inn, erected in 1832 at Clinton,

Mich., will be in charge of students of hotel management and nutrition and will serve meals to the public. And so on through every industry that is represented.

The machine-shops and foundry will actually produce practical models, equipment and fixtures for students of metallurgy and chemistry now engaged in research in the Edison laboratory.

In the glass house where Edison's men blew the first pear-shaped globes that held his precious filaments, students will learn the almost extinct art of the glass-blower. This includes the production of the familiar fancy pieces of earlier times and also the chemical apparatus necessary in the laboratories. The tintype studio serves a very practical purpose in Mr. Ford's program of education and of preservation of the past. Tintypes are made of visitors, and research work in progress looks toward the revival of the daguerreotype process, at present a lost art. Technical writers of the time of the daguerreotype failed to record its processes.

Even the colonial church, named the Chapel of Martha and Mary after the mothers of Mrs. and Mr. Ford, will serve the students. In the steeple hangs a bell cast by the silversmith, founder and master craftsman, Paul Revere. A $30,000 organ has been installed for students of music and of instrument building. The church, which is non-sectarian, will be open every day of the week.

The little red schoolhouse where Mr. Ford studied from the McGuffey readers is now attended by 32 youngsters in the first four grades of grammar school.

Series of Period Architecture

The development of architectural science is illustrated by a series of buildings belonging to various periods, first of which is a house brought from the Cotswold country of England. This house, dating back to the 10th century, is of the four-walls and high-peaked-roof style. Next to that will be one of the early types of American homes erected by the Pilgrims. Among others is a house dating back to 1750, a log-cabin typical of the western pioneer's shelter, a home of 70 years ago, and a boarding house of 1870.

The Edison group comprises his Menlo Park laboratory, machine-shop, the first dynamo electric-plant for incandescent lighting, office and library, carbon shed, glass house, Sarah Jordan's boarding house (the first home lighted by the incandescent lamp) and the Fort Myers, Fla., laboratory. It was here that the 50th anniversary of the incandescent lamp was celebrated.

Luther Burbank's office from Santa Rosa, Calif., is near the east boundary of the village by a forest that is to become a bird sanctuary to be dedicated to the memory of John Burroughs. On the banks of the River Rouge, the small stream running through the village, will stand the camp of Charles P. Steinmetz, much as it did in its original location near Schenectady, N. Y. Other buildings are being included in the unique community, to the end that all important trades and industrial arts shall be shown in their original settings, each operating and self-supporting.

Summer-Meeting Plans Announced

Meetings Committee Outlines a Program Showing Judicious Blending of Work and Recreation

THE 1930 Summer Meeting, as previously announced, will be held at French Lick, Ind., May 25 to 29 inclusive. The members who attended either the 1926 or the 1927 Summer Meeting, recalling the splendid facilities afforded by French Lick Springs for the varied activities that make up a successful Summer Meeting, will look forward to the last week in May with pleasurable anticipation. The members who were not present at either of those two events but plan to attend this year's Summer Meeting will find, among the attractions at French Lick, unexcelled equipment for the holding of technical sessions and committee meetings, splendid provision for recreational activities, and the inestimable advantage of a hotel capable of housing the entire attendance under one roof.

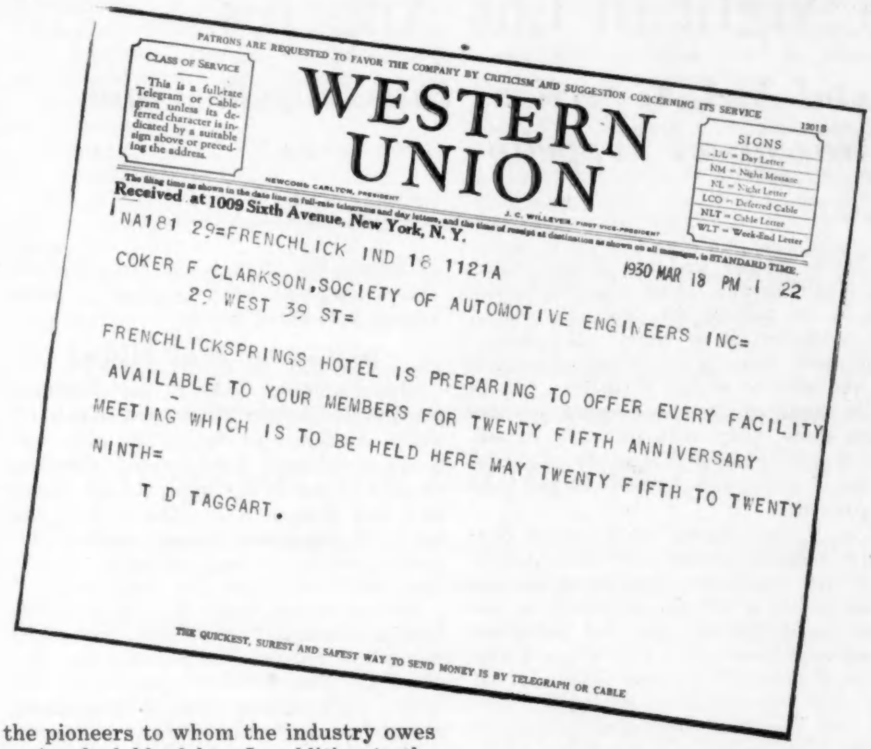
Chairman John Warner and the members of the Meetings Committee, recognizing that a Summer Meeting is a combination of technical and recreational events, have made it their aim to combine those interests properly and in the correct proportions, and the program has been designed with that idea in mind. The mornings and evenings will be devoted to serious interests, namely, technical sessions, business sessions and committee meetings; the afternoons will be left open for recreational activities. Facilities will be available for golf, tennis and archery, but the only organized sports-event, other than the golf tournament, held during the week will be the Field Day, which is to be of a humorous character, similar to the Field Day so thoroughly enjoyed by those who attended the 1929 Summer Meeting.

Twenty-Fifth Anniversary Celebration

Ten technical sessions have been planned, in addition to the Semi-Annual Business Meeting, a Standards Session and two evening sessions of a general character. The first of these general sessions, tentatively scheduled for Sunday, the opening evening of the Summer Meeting, promises to be an event of unique interest, because of the fact that on that occasion C. F. Kettering, the incomparable "Ket", will tell about his trip to the Galapagos Islands.

The other general session, which probably will be on Wednesday evening, will be a dinner, celebrating the 25th anniversary of the founding of the Society and featuring the old-timers,

FRENCH LICK SPRINGS HOTEL AND GROUNDS WHERE 25TH ANNIVERSARY MEETING OF THE SOCIETY WILL BE HELD, MAY 25 TO 29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the pioneers to whom the industry owes an incalculable debt. In addition to the dinner, the 25th anniversary will be celebrated by an extensive exhibition, portraying the progress made in the automotive industry during the last quarter-century. It is planned to bring together, in addition to pioneer members of the industry, early models of motor cars, accessories, airplanes, motorcycles, and other automotive products, early photographs, newspaper magazine and trade paper presentations of advertising and editorial pages, exhibits from the Army and Navy, the Smithsonian Institution and private collections.

Seven of the Professional Activities of the Society are sponsoring technical sessions at the Summer Meeting. Sessions on Diesel engines, aircraft engines, aircraft, transportation and maintenance, motor-trucks and motorcoaches, and automobile bodies are being planned by the Activities interested respectively in these topics; and the Passenger-Car Activity is sponsoring a session on transmissions, one on brakes and one on gasoline engines. A Research Session is being arranged by the Research Committee.

More detailed information regarding Summer Meeting plans will be given in the May issue of THE JOURNAL.

Metropolitan Aeronautic Meeting

Two-Day National Meeting To Be Held During New York Aircraft Show

FOLLOWING closely on the Detroit Aeronautic Meeting in April, the third series of aeronautic engineering sessions in 1930 will be held in the Park Central Hotel on May 6 and 7. This Metropolitan Aeronautic Meeting is being sponsored by the Aeronautic Division of the Metropolitan Section of the Society and calls for four technical sessions and a dinner, the latter to be held on the night of May 7.

While at this time the entire program is not complete, sufficient arrangements have been made to give definite information concerning the major part of the program.

First Day's Two Sessions

Two sessions will be held on Tuesday, May 6, the morning session to be on engines, with George W. Dunham presiding as Chairman. Two papers comprise the forenoon technical program; namely, In-Line Liquid-Cooled versus Air-Cooled Engines, by George J. Mead, vice-president of the Pratt & Whitney Aircraft Co.; and A New Mechanical Motion Applicable to Prime Movers or Auxiliaries, by D. Douglas Demarest, consulting engineer.

The afternoon session will be devoted to marine air transport, with Virginius E. Clark, of the Aviation Corp., acting as Chairman. While there will be two papers in this session, only one has been definitely arranged for; namely, Transoceanic Air Travel, by Jerome C. Hunsaker, of the Goodyear-Zeppelin Corp. It is anticipated that the second paper will be on Amphibian Aerodynamics, although the author has not definitely been chosen.

Second Day's Interesting Features

The morning session, on Wednesday, May 7, will be presided over by Edward V. Rickenbacker, of the Fokker Aircraft Corp., and the papers will treat of two very interesting and unusual subjects in aircraft design. Lieutenant Schildhauer, of the Dornier Corp. of America, will talk on Construction Details of the Dornier DO-X. It is hoped that the excellent motion pictures which were taken of this remarkable ship in flight will be available to accompany Lieutenant Schildhauer's address.

For the last several months, ever since the advent of the Autogiro in this Country, a great deal of development work has been going on looking toward the improvement in design and performance of this type of flying-machine. Foremost among those interested in this problem is W. Laurence LePage, of the Kellett Aircraft Corp., which is spending its entire resources in the development of a new Autogiro. Mr. LePage will discuss the recent developments in this field in a paper entitled, The New Autogiro.

The afternoon session, Wednesday, will be devoted to research and experiment and will be conducted under the Chairmanship of Theodore P. Wright, chief engineer of the Curtiss Aeroplane & Motor Co. While this session will have two papers, at the present writing only one has been definitely determined upon. A very interesting treatise on speed flying will be given by Lieut. Alfred Williams, the speed expert of the United States Navy.

Dinner with Aeronautical Chamber

As a climax to the meeting, a joint dinner of the Society and the Aeronautical Chamber of Commerce will be held at 6.30 Wednesday evening, May 7. The toastmaster will be Henry S. Breckinridge, and the speaker of the evening will be Fred. B. Rentschler, of the Pratt & Whitney Aircraft Co., who will talk on Transportation versus Air Circus. Present plans call for a short dinner similar to the Annual Dinner of the Society, starting promptly on time and finishing not later than 8.30 p. m., to give an opportunity for those in attendance to use the balance of the evening for such pursuits as they may desire.

Dirigible Night in Los Angeles

Members of S.A.E. and N.A.A. Sections Dine Together and Hear about Zeppelins

THE construction at Akron, Ohio, of two huge dirigibles for the United States Navy, which will dwarf the Graf Zeppelin, was explained by V. R. Jacobs, Goodyear Zeppelin sales manager, to members of Southern California Sections of the Society of Automotive Engineers and the National Aeronautic Association at their joint dinner meeting in Los Angeles on March 14.

The night was "dirigible night" and more than 450 members from the two organizations were present. Members of the Aeronautic Association were present at the invitation of the S.A.E. Section, which had invited Mr. Jacobs to speak. Leigh M. Griffith, of the S.A.E., and Robert J. Pritchard, of the N.A.A., were joint Chairmen.

The dirigible expert poured forth a steady stream of interesting information and data on Zeppelins, for both commercial and military purposes. The two Navy airships, he said, will be three-quarters larger than the Graf Zeppelin, and will be the largest in the air. The first, on which most of the experimentation was done, will cost $5,500,000. The second, which benefits by the experiences in making the first, will cost $2,500,000. All engines and mechanical parts except the propellers will be inside the big fabric covering so that mechanics can make repairs while the ship is in the air.

Each dirigible will carry inside its hull five airplanes that can be lowered from the airship and flown away, or hooked on while in flight and hauled up through a trapdoor to a 30 x 70-ft. "hangar." In this way, Mr. Jacobs explained, they can be released to protect the dirigible in case of attack from the air, or can be lowered away to deploy on scouting and attack flights and use the blimp as a mother-ship. This feature is claimed to be especially practicable in commercial flying. Huge dirigibles carrying cargoes across the Country can unload articles for certain destinations by sending them to the ground in airplanes released from the keel of the airship.

The construction of these airships illustrates the rapid growth in the size of dirigibles. The Los Angeles was one of the first. Then came the Graf Zeppelin, which was larger. Later, the British built the R-100 and the R-101, which were still larger. And now the United States is taking the lead, he stated, by outdoing all of them. Mr. Jacobs said that there is no known limitation to the size to which dirigibles can be built, and, as far as present designs have gone, they will increase in efficiency up to 15,000,000-cu. ft. capacity, which is about 150 per cent larger than at present.

The United States leads among Zeppelin manufacturers now, Mr. Jacobs told the engineers and aviators, because it has a virtual monopoly of the sources of helium gas for inflation. Leading deposits are in Texas, Oklahoma, Kansas, Utah and Colorado. If Germany poured all of its helium supply into the Graf Zeppelin, he said, it would take 40 years to fill it, provided none leaked out.

A process for "filtering" helium after it has become mixed with oxygen has been devised so that the pure helium can be re-used.

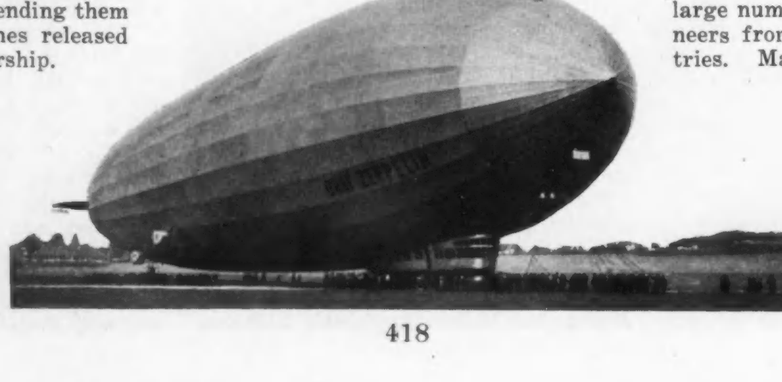
In answer to a question, Mr. Jacobs stated that a mixture of 20 per cent helium in hydrogen will make the hydrogen non-inflammable and the mixture will have greater lifting power than pure helium. He told of the plans of the Goodyear-Zeppelin Corp. to build more airships and carry freight and passengers from the Pacific Coast to Hawaii and the Orient. The enormous lifting power of lighter-than-air ships in proportion to their total weight makes them valuable for hauling heavy cargoes long distances. The airplane, he stated, will be used for fast travel over comparatively short distances, but the dirigible will be used ultimately for more leisurely trips and for carrying express over long routes. Nevertheless, dirigible travel will be considerably faster than by steamers and most trains. The average speed of an airship is 75 m.p.h., and the best speed that has been attained in calm atmosphere is 85 m.p.h.

Incidents of Blimp Piloting

Bud Campbell, pilot of the Goodyear semi-rigid airship Volunteer, told humorous incidents of flying the ship and a "pony blimp." He related shooting motion pictures of Custer's Last Stand and Bob Hampton of Placer from the air with Marshall Neilan, motion-picture director. A negro cavalry detachment was recruited for "redskins."

On a whale hunt in Los Angeles harbor, Campbell narrated, the party narrowly missed harpooning a submarine. The weather was foggy, he said, and the airship was drifting along a few feet above the water. Suddenly someone sighted a long black streak in the water, resembling a whale. The harpoon was poised. Just at that moment, Campbell declared, the sun shone through the clouds and the airmen found themselves directly over a submarine. "If we'd dropped that harpoon through the conning tower of the sub, thinking it was a whale, we'd still be looking for it on the bottom of the harbor," he asserted.

The training which young men go through to become pilots of lighter-than-air craft is rigorous, explained Lieut. Karl Lange, a graduate of Annapolis Naval Academy who is now engineer and pilot for the Goodyear company. He said the men have to learn to fly in everything from balloons to blimps. BOB HAYES.



Syracuse Section Formed

On March 14, in Syracuse, N. Y., a group of 40 members of the Society and their guests assembled in the rooms of the Chamber of Commerce and voted to organize a local Section to be known as the Syracuse Section.

The meeting was attended by a large number of representative engineers from various Syracuse industries. Many letters were received prior to the meeting from persons in the surrounding territory who were anxious to start such a Section but were unable to be present. A great deal of the credit for the early organization work belongs to R. B.

Beauchamp, of the H. H. Franklin Mfg. Co., who has been an enthusiastic and interested member of the Society in both Syracuse and Detroit.

The temporary officers elected were as follows:

Chairman—E. S. Marks, of the H. H. Franklin Mfg. Co.

Vice-Chairman—Charles P. Grimes, of the Grimes Brake Engineering Service

Secretary—Lloyd W. Moulton, consulting engineer

Treasurer—M. R. Potter, of the Allen Cadillac Corp.

In addition to these officers, the following Nominating Committee was elected to choose nominees for the various Section offices for the ensuing year:

R. P. Lay, of the H. H. Franklin Mfg. Co., Chairman; John E. Shea, of the Continental Baking Corp.; R. B. Beauchamp, of the H. H. Franklin Mfg. Co.; and W. H. Emond, of the H. H. Franklin Mfg. Co.

Meetings are to be held monthly at the Hotel Syracuse or in some similar quarters and will be preceded by a dinner. Definite plans call for a first meeting on April 15, with an address by Edward P. Warner.

Nevertheless, Airplanes Do Fly

Detroit Aeronautic Division Learns of Problems Besetting Airline Operators

PAUL HENDERSON, general manager of the Transcontinental Air Transport, who was introduced to the Aeronautic Division of the Detroit Section as "Lindy's boss," was the speaker at the Division's meeting on March 3 at the Book-Cadillac Hotel. In words that flowed easily but vibrated with facts and experience, Colonel Henderson gave to the numerous members who were in attendance a very clear picture of just what problem the operators of airplane lines must contend with, how some of their tasks have been solved satisfactorily, and what are the expectations for finding effective solutions for the questions that still remain.

Colonel Henderson touched upon legal, engineering and management matters, and had some interesting observations to make on them all. He dwelt on the fact that the present law, as it affects aviation, is still very much in flux, so that it is often impossible for the owner or operator of an airplane or of a fleet of planes to ascertain what his rights are. Accordingly, much of the behavior of the men behind the airplanes, in dealing with the world at large, has to be improvised as they go along. Plane-operating companies do not even know, so far, whether they are common or private carriers; for example, whether they have a real right to refuse passage to a sober person desiring to buy it. When it comes to forced landings and the multitudinous questions arising from them, the airplane operators and pilots simply have to be ingenious in meeting whatever conditions may develop.

Impediments to Aviation's Growth

"What is the matter with aviation" was summed up by Colonel Henderson about as follows:

Aviation—I suppose, in common with other businesses—has had poured into it altogether too much money during the last few years. Only a few years ago our dreams always went on the rocks because of our inability to get the money necessary to do the job. Now, strange to say, we have been thrown into the rather trying position of having too much money. The aviation industry now has so much money, and so many things that are half-baked in character have been undertaken, that we all have a very acute case of indigestion. Whether we can digest this money and save it, the next 18 months will tell.

Obsolescence and Operating Cost

With regard to correct operating costs, the speaker said they were about as difficult to determine as the legal points. The reason therefor is the intricate question of depreciation. Estimates for a given type of airplane vary from a life of 2000 hr. to one twice as long. As a matter of fact, however, depreciation bothers operators less than "Old Man Obsolescence."

"The airplane of today," said Colonel Henderson, "is likely to be completely old-fashioned and obsolete a year from today. It is really this rather than strict depreciation that must be weighed. In the National Air Transport, three different types of airplane were discarded while they were still as efficient as when they were new; but they were no longer serviceable, because improved airplane types had come along to take their places.

"There is a similar mystery about passenger rates. We have learned that a great many people will fly at 5 cents a mile. What shall we do; continue to charge them 5 cents and try to find some way to run airplanes at that cost, or gradually push rates up to 6½ or 7½ cents and hope to come out even? Some men in the business believe we shall never be able to come out even until airplanes have enough seats so that, even with a rate as low as 5 cents a mile, the cost will be returned. An airplane carrying 32 persons is now in operation, and five or six such machines will be ready in a few weeks. There are others, smaller than the airplanes we have been using, seating about ten persons. The Germans and the French, until recently, were convinced that the answer was the airplane for 30, 50 or even 100 passengers; but within the last three months they have reversed their position and are now replacing the 15 and 20-passenger airplanes with 4-passenger planes."

Question of Engine Overhauls

The speaker then turned to the question of how often an airplane engine should be overhauled, and said:

Our experience in the National Air Transport has been that Liberty engines, of which we are using many, can be run 500,000 miles between difficulties. That does not mean between overhauls. We overhaul them every 250 hr., but our record now is 500,000 miles before being brought down by forced landings. Many of them were built in Detroit during the war.

Another remarkable thing about these engines is that we can take a given part off the Ford engine, another part off a Marmon engine, and still another part off a Lincoln, and the parts are interchangeable even at this late date; therefore most of our engines have long since lost their identity.

Our method of handling them is to bring the engines in at the end of a 250-hr. period, completely dismantle them, inspect the parts and put them in stock and reassemble new engines out of the general parts stock. There may be a Ford crankshaft in a Marmon crankcase, and cylinders by several manufacturers, yet they do not fail to fit. I think that is a great tribute to the men who made the engines ten years ago.

Radical Developments May Come

In conclusion, Colonel Henderson expressed the opinion that the two most fertile fields for engineering and inventive genius in the airplane business are offered by the problems of ice formation and of blind flying; unless, of course, some revolutionary development is in the offing. The speaker thought that this is possible, pointing out that the modern airplane in its contours is as yet not greatly dissimilar from the original Wright airplane of 25 years ago. He said that perhaps airplanes should be built along wholly different lines than they are; in fact, a very good designer on the West Coast is now working on an airplane that "is nothing but a wing with two struts running through the tail surfaces, with all of the power and cargo inside the one flying wing. That may be a great step forward; I do not know whether it is or not; but we are making steps forward."

An Aircraft-Welding Meeting

THE Wichita Section held an aeronautic meeting Wednesday, March 12, with about 60 members and guests in attendance. Welding in Aircraft Construction was the subject presented

by A. K. Seeman, of the Linde Air Products Co., who presented again parts of a paper which he read before a meeting of the Section last November, together with new material on the same subject.

Other features of the meeting were a very interesting animated picture showing autogenous welding as applied in various industries, and a demonstration of a hydraulic tension machine developed by the Union Carbide & Carbon Corp. for testing welds. This demonstration was given by W. R. Clark, of the Wichita branch of the Linde Air Products Co.

Aircraft-Carrier Operations

Chicago Section Views Motion Pictures of Recent Navy Practice and Hears Lieutenant Webb's Description

FOLLOWING the short business session held at the Chicago Section Meeting on March 11, at the Sherman Hotel, at which the Section's Nominating Committee was designated to prepare a slate for officers for the ensuing year, an interesting paper was presented by Lieut. L. D. Webb, of the United States Navy, on the subject of Operations of Aircraft-Carrier Aviation. The Section members designated as the Nominating Committee were: J. W. Tierney, Frank C. Mock, Harry F. Bryan, John S. Erskine and J. P. McArdle. The meeting was conducted by D. P. Barnard, 4th, Chairman of the Section.

Shipboard Launchings and Return Shown

Lieutenant Webb's paper was similar to the one he presented at the Metropolitan Section meeting in New York City in December, 1929, an account of which was printed in the January, 1930, issue of the S.A.E. JOURNAL, p. 10. Airplane-carrier operation was shown to the 90 members and guests who were in attendance at Chicago by motion pictures of normal take-offs and landings and included the launching of a deck load of airplanes in succession, together with slow-motion pictures of the action of the arresting gear.

Following the paper and the showing of the pictures, numerous questions were asked by those present and were answered by Lieutenant Webb. Among his answers were included the statements that special tail-skids are not used, the latest design having an oleo leg very similar to that used in landing-gears; that roll of the vessel as much as 10 or 15 deg. makes little difference in landing on ship deck; that fore-and-aft pitch interferes with landing more than does roll; and that the carrier Lexington furnished all the light and power for a month, following an emergency condition, to the cities of Portland, Ore., and Tacoma, Wash.

The total complement of an aircraft-carrier ship is about 1500 men, about 200 of whom are members of the aviation personnel.

Lieutenant Webb remarked that no airplanes are being operated on submarines at present, but that this is a line of development under investigation at present. The bow of the airplane carrier shown, over which the airplanes were launched, was about 45 ft. above the level of the sea. The slipstream from the preceding plane is likely to cause trouble for the airplane behind unless an adequate space is maintained between the plane that has taken off and the one that is to follow. This is the limiting factor of the time of taking off and a definite interval is therefore maintained between the take-off of two or more airplanes.

Many variables affect the length of time required for an airplane to take off, the main one being the wind-speed over the deck. An instance was given of spotting some of the airplanes on the deck 100 ft. from the bow when there was a 40-m.p.h. wind over the deck; but it was said that if the speed of the wind had been only 15 m.p.h. the airplanes would need to have been spotted considerably farther back toward the stern. A chart showing varied spotting conditions of loading for all types of airplane under various wind-speeds over the deck is available, and is used to spot any particular plane at any specified air-speed and still give the pilot room enough to take off without having to depend on the drop of the airplane over the bow so as to attain flying speed.

A description of an airplane catapult was given by Lieutenant Webb, who also answered a question by Chairman Barnard by saying that airplane carriers have a great amount of special fire-fighting equipment. For example, the hangars in the interior of the ship are equipped with 16 foamite extinguishers of 200-gal. capacity which furnish foam to a belt line leading all the way around the hangar and to which from 16 to 18 reels of hose are attached. In addition, there are the sprinklers and water fire-curtains as well as the usual hand fire-extinguishers and the salt-water fire-protection equipment.

How Not To Be Shocked

Watson Gives Philadelphia Section Members the Low-Down on Springs and Shock-Absorbers

TO THOSE who measure the success of a meeting by the amount of extemporaneous discussion the speaker can invoke, the Philadelphia Section meeting on March 12, at which John Warren Watson informally let those present in on the real "low-down" of shock-absorber application and installation, was the best of the season; and this is saying something in view of the many successful meetings this Section has had lately, measured by this or any other standard of comparison.

Mr. Watson, in his talk on How To Design for an Easy Ride, told Section members the primary or essential factors upon which any shock-absorber installation must be based and how they can be measured, in terms not theoretical or mathematical, but in plain everyday language, of engineers of course. He stressed the importance of correctly determining the periodicity of the springs, front and rear, not only as calculated, but as measured when installed in the car. He then described how this can be determined in a practical way, as the result of his experience with the many cars on which he has worked.

It is Mr. Watson's opinion that there are certain limiting periods of up and down motion which, if exceeded in speed or rapidity, result in discomfort to the car occupants. For front springs this period is around 100 cycles per minute, and for rear springs 75 to 80. Even better riding-quality can be had by keeping the periods lower than these. They are determined by actually bouncing the car through the agency of a man weighing from 150 to 160 lb. with the car empty of passengers. Since the period is lowered with increase in spring weight, the determination in this way assures a slower period when the component of passengers is included.

To arrive at the correct spring dimensions, Mr. Watson proceeds first to obtain periods within the limits mentioned by removing leaves from the springs on the car, then measures the rate of the altered springs and designs new springs having the desired characteristics.

Coordinate Spring Design with Absorbers

One of the fundamental requirements of easy riding was shown to be adequate control of unwanted oscillation in checking rebound; that is, in absorbing the potential energy of the compressed spring with adequate force. With this as a basis, Mr. Watson believes that the car designer should first determine the type and make of shock-absorber he plans to use regularly, then design the springs around the shock-absorber, rather than following the present practice of completing the entire vehicle even before the shock-absorber manufacturer has an opportunity of entering into the solution of the problem.

He strongly decried the idea of leaving the installation of the absorbers until the last minute, and then blaming unsuccessful performance on the shock-absorbers; for he feels that no shock-absorbing medium, no matter how adequate, can cope with improper spring design, as often manifested by the use of too short front springs, too stiff springs, shackles that permit of too tight adjustment and many other elements affecting spring operation, even though these conditions had seemingly been thought necessary to overcome other problems such as tramping and shimmy.

Since the hydraulic type of shock-absorber is at present the most popular, Mr. Watson confined his further remarks entirely to a description of the advantages and disadvantages of this type, illustrating his point with crayon drawings of their general design.

Discussion Exceeded the Limit

The discussion of the talk opened with the proverbial "bang" and continued well past the usual limit. The number of questions asked by designers and service men seemed endless and grew in interest up to the time the Chairman of the meeting, B. B. Bachman, finally had to call a halt. Instead of concluding as usual at 10 p.m., an additional hour was not enough, even after limiting the discussion to a few minutes for each questioner.

The influence of such factors as wheel-base length, speed, viscosity of fluid in the shock-absorber, relationship of sprung to unsprung weight and many others were aired from every angle by the discussers.

When the Philadelphia Section says, as it did in this instance, "Get the low-down" on any selected subject, one can be sure that the members and guests will not be sorry they attended. At the dinner preceding the meeting more than 50 members were present, with close to 75 hearing Mr. Watson's talk. A short entertainment was provided during the meal.

B. B. N.

"I have had the time of my life: sports, social events, papers and discussions—just one hundred per cent."

Will YOU be able to say so on Memorial Day, after the close of the

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25th

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1930 Summer Meeting

at French Lick Springs, Ind., May 25 to 29?

Read the Meeting details on p. 416. It will help you to make up your mind. And—

Send in your reservation *early*.

Pittsburgh Section Going Strong

March Meeting on Gasoline Attended by 200, Who Hear Two Good Papers

WITH three good speakers, 200 members and guests present, good music, and good eats in a good place to meet, the March 20 meeting of the Pittsburgh Section was fully up to the high standards set at the Section's previous meetings.

A brief business meeting that *was* brief resulted in the selection of Samuel P. Marley, Prof. James W. Trimmer, Eugene H. Gray, A. R. Platt and Clyde C. Mathis as a committee to nominate officers for the coming year, to be inducted into office at the next meeting of the Section.

Professor Trimmer then introduced the speakers of the evening.

Arthur J. Underwood gave a short talk on the advantages of becoming a member of the Society, especially when it is backed up by an active local Section giving an opportunity for personal acquaintanceship and good-fellowship.

Gasoline Affords Entertainment

Dr. W. F. Rittman, of the Carnegie Institute of Technology, inventor of the Rittman cracking process and consulting engineer for many large refining companies, spoke entertainingly on the production processes used in providing gasoline, from the taking of the crude oil "from a hole punched in the ground" to the gasoline filling-station pump ready for delivery to the car. He explained why gasoline is not what it used to be and might be something else again by tomorrow, saying that it is not a simple element but a complex blend of "all the letters of the alphabet and some of the numbers."

It was interesting to learn that from 100 gal. of crude oil many of the refiners are now averaging 60 to 70 gal. of gasoline. Many refiners could go higher than this, but at present prices it is not profitable to do so. In spite of this, and perhaps as a matter of pride, some refiners are actually achieving almost 100 gal. of gasoline from the same number of gallons of crude oil.

Answering a question as to why there was once such widespread interest in kerosene-burning carbureters and so little had resulted along these lines, Dr. Rittman explained that present control of refining methods results in very little differential in cost, at the refineries, between kerosene and gasoline, possibly only 2 cents per gal., and that the advantages in easier starting and flexibility possessed by gasoline far outweigh such a slight cost differential.

Speaking of "premium" fuels, Dr. Rittman explained the widespread sale of such fuels on the basis of better performance; a premium fuel "picks up faster, doesn't knock, gives more miles per gallon," were the reasons given by many buyers. Possibly this preference is an evidence of the luxury complex of the American public, for buyers of such fuels seem to be as frequent among owners of less expensive cars as of those that cost more. The "regular" gasoline probably "contains as many miles per gallon" as does the higher-priced fuel, but the car owner credits the premium fuel with better mileage, because it makes the car easier to drive, according to the speaker. He described how more volatile fuel might often average even fewer miles per gallon, but what the public wants is more power and "pep."

How Fuel Gets Het Up

The application and use of gasoline in the car was described by W. G. Lovell, assistant head of the fuel section of the General Motors Corp. Research Laboratories, who explained with charts and diagrams the service requirements of fuels, such as mileage, power, and knocking tendencies. The

first chart showed the rise in temperature of gasoline in a typical car running at normal speed on a summer day: how the comparatively cool gasoline in the tank becomes warmer as it passes through the fuel line, and still warmer as it passes through the fuel-pump or vacuum tank and the carbureter. The second chart showed a considerable increase in these temperatures when the car is at rest and the engine idling. Which explained very neatly why an idling engine, which is running evenly, will often stop, apparently without cause—vapor lock!

Gum in the gasoline was shown to be a fact by samples of "gummy gas" and horrible examples of the actual results caused by the use of such fuels. The need for stability in fuels, particularly for quantity buyers, was shown by Mr. Lovell, who did not have to dwell on the disadvantages of gum in the fuel-pump or carbureter. It is better to park our gum under the steering-wheel than in the carbureter, the hearers learned.

An interesting discussion followed, and the evening ended with the distribution of attendance prizes. M. F.

Engine-Lubrication System

Cleveland Section Members Hear Darnell Stress Importance of Oil-Circulation Problem

THE influence exerted on oil circulation and contamination by various designs of lubrication system was the theme of R. C. Darnell, chief engineer of the Taylor Bros. Mfg. Corp., of Elkhart, Ind., who addressed the March 10 meeting of the Cleveland Section. Before listening to the speaker of the evening, the 99 members who assembled at the Hotel Cleveland held a brief business meeting at which the members of the committee to select candidates for the various Section offices for the next administrative year were elected. Those chosen were S. L. Bradley, sales engineer, Ross Gear & Tool Co.; R. W. Brown, Firestone Tire & Rubber Co.; A. K. Brumbaugh, commercial engineer, White Motor Co.; A. A. Skinner, general sales manager, Leece-Neville Co.; and E. W. Weaver, automotive engineer, Trundle Engineering Co.

Review of Early Systems

Before presenting an analysis of present designs of engine-oiling systems, discussing some of the difficulties incident to lubrication and describing the operation and results of a new development in engine lubricators, Mr. Darnell reviewed briefly the various types used in the past. The first of these was the old steam-engine side lubricator mounted on the dash. This "all loss" system, despite its crudity, fed clean uncontaminated oil. A single drip-feed glass that fed the lubricant drop by drop into splasher or gravity troughs was the next refinement. Semi-pressure systems that force oil at relatively low pressure to the main bearings followed and were in turn succeeded by the full-pressure system used on the majority of the motor-cars in use today. Except for the location and operation of the relief valve and the operating pressure, all of these full-pressure systems are essentially the same.

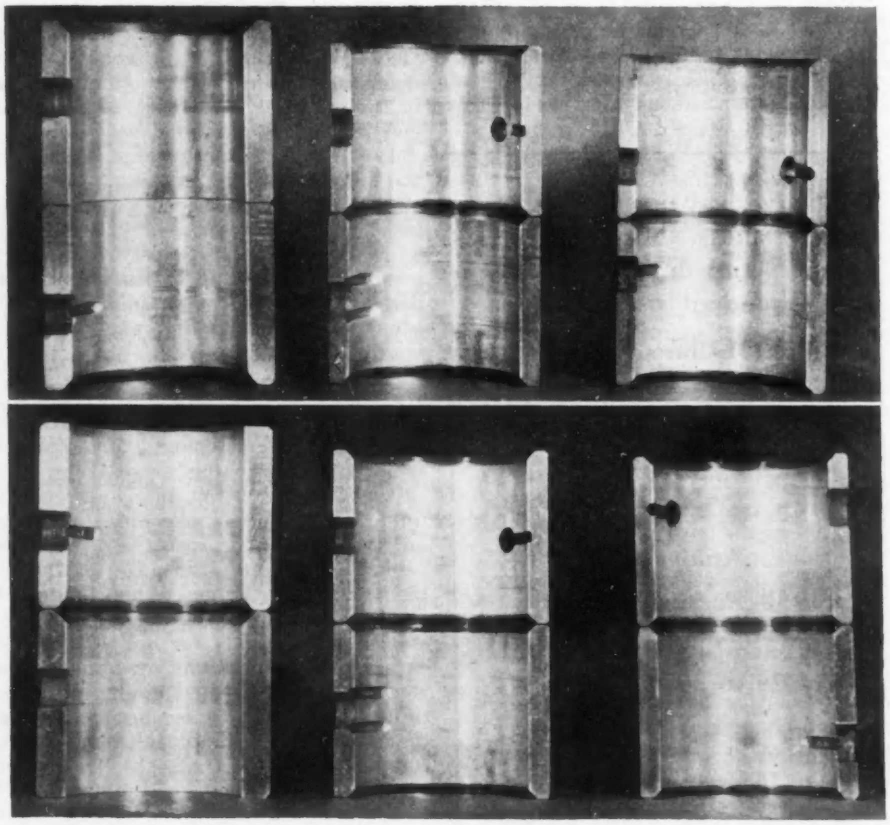
Circulation of grit and metallic sediment was one of the major difficulties with the full-pressure system, the speaker said, and in an effort to overcome this the dry-sump system with temperature control was developed. A further step toward contamination elimination was the use of oil-filters.

Circulation of grit in the engine can be controlled to some extent by the design of the oil pan. To prevent oil cavitation or loss of pressure with brake application, the suction inlet to the pump is located close to the bottom of the pan in many cases. As the pump is started, oil currents of sufficient violence to disturb the foreign particles and place them in circulation are produced. These troubles can be overcome by an oil-pan design that minimizes the danger of losing pressure with brake applications and reduces the possibility of dislodging the foreign particles by increasing the depth of the pan.

Lack of a protective oil-film, together with contamination, is the fundamental cause of engine deterioration. Some very constructive work, in Mr. Darnell's opinion, can be done by the engine designer to remedy the fluctuations in oil pressure so common for the first 10 or 15 min. after an engine is started in cold weather.

Novel Device Eliminates Lubrication Troubles

To offset the shortcomings of present systems and eliminate such troubles as result from circulation of contaminated oil, accumulation of water in the system and the possibility of a frozen oil-pump suction, the Floato oil-suction



HOW THE FLOATO SUCTION-INLET INFLUENCES BEARING WEAR
Both Photographs from Which This Illustration Was Made Are Unretouched and Show (Top) a Set of Bearings After 15,000 Miles of Driving in a Car Equipped with a Conventional Lubricating System, and (Bottom) a Set Taken from a Car Equipped with the Floato System After Covering the Same Distance

inlet has been developed. The essential elements of the device, as described by the speaker, are a float that supports one end of the oil-pump suction, a coarse-mesh screen across the float bottom, and a shield that is also attached to the bottom of the float. The function of the float is to provide a source for the lubricant which is relatively high above the bottom of the oil pan, thus assuring a supply of clean oil. Lint and similar particles floating in the oil are removed by the screen, and the plate serves to prevent the contamination in the bottom of the oil pan from being disturbed by the currents produced by the oil-pump when the oil level is low.

Tests of the device have been made to determine the quality of the oil circulated under various conditions, ability to maintain circulation under low atmospheric conditions, relative oil-temperatures at different depths from the surface of the oil pan under actual road conditions, and wear conditions in bearings as compared with filter equipment. The results of these tests were satisfactory, said Mr. Darnell, the oil remaining free from foreign particles and water even when the pan was only one-quarter full.

The ability of the device to circulate oil at low temperatures was tested in a room having a temperature of 0 deg. fahr. At the commencement of this test the temperature of the oil was also 0 and its pressure was 28 lb. This pressure was maintained constant throughout the 28 min. the test was run. At the conclusion of the test the oil temperature had risen to 19 deg., which was high enough, because of the constant circulation, to be well above the danger point of losing oil pressure.

The influence of the device in preventing wear of the bearings is brought out in the accompanying illustration showing a set of bearings after 15,000 miles of driving in a car equipped with the conventional lubricating system and a set after a car in which the Floato system was installed had covered the same distance.

The discussion following the presentation of the paper was participated in by a number of those in attendance and was confined for the most part to amplification and clarification of various points brought out in the paper.

Industrial Engine Subjects

Waukesha Engineers Address Milwaukee Section on Industrial Designs and Applications and Diesel Engines

FOLLOWING the success of its February meeting on tractors, the Milwaukee Section moved on to the adjacent subject of industrial engines, in the manufacture of which the district has also a large stake. After dinner at the Milwaukee Athletic Club, Chairman Arthur C. Wollensak called to order a group of 145 members and guests. Milwaukee, it seems, is quite a capitalistic city. In February it was proclaimed capital of the tractor industry, and the Chairman's remarks at the March meeting proclaimed it the logical capital of the road-building-equipment industry.

Papers were presented by three engineers of the Waukesha Motor Co. James B. Fisher acted as Chairman during most of the meeting, Chairman Wollensak resuming the chair during the reading of Mr. Fisher's paper. The papers presented were intended more to promote discussion than to give information on any definite product, and they were successful in eliciting informative remarks from prominent engineers connected with a number of the local manufacturing organizations.

In his paper on the Industrial Applications of the Automotive Engine, L. L. Bower, installation engineer, gave a long list of industrial uses for engines, among them being the driving of air compressors, combine harvesters, excavators, feed mills, pavers and shovels and various operations in logging and oil-field work. The agricultural demands are growing constantly.

Mechanical shovels impose a succession of peak loads, which can be well met by using flywheels that are larger than customary. Mr. Bower said that a suitable flywheel can add at least 30 per cent to the power of an engine during a peak load, at the expense of a speed drop of 100 to 150 r.p.m. A quick-acting governor is needed, to prevent a speed drop below the speed of maximum power. Manufacturers of such equipment make it so that excessive loads will stall the engine rather than cause breakage.

Gas Fuel in Oil Fields

Natural gas is being used as fuel for internal-combustion engines in oil fields. This is the cheapest fuel to be found anywhere, according to Mr. Bower. In some cases it is being burned as waste; for instance, in Alberta, Canada, nearly 200,000,000 cu. ft. of gas is being burned daily as waste. Casing-head gasoline, sometimes known as "wet gas," is sold for fuel under the names of butane and propane. The virtually negligible consumption of water, which is characteristic of automotive engines, is often a great advantage in dry localities.

For oil-field work, engine manufac-

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The details are found on page 416.

* * *

Summer Meeting habitués will, of course, be at French Lick Springs. But there will also be hundreds of others, expectant and assured of a highly enjoyable experience.

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* * *

Naturally, you want to attend this anniversary of your Society, that will demonstrate the importance of the automotive engineer in the modern world.

So please send your reservation as early as you can manage it.

* * *

And by the way, French Lick Springs offers the chance of a very pleasant week end, Memorial Day to June 1, 1930.

turers furnish self-contained units, complete with cooling equipment, clutches and reduction gears. Sometimes reversing also must be arranged for, and one application includes a reversing transmission and clutch mounted on the engine in such a way that it can be controlled by a single lever, much as a steam engine is reversed. Such units often are mounted on steel skids so that they can be dragged over the ground by tractors when changing location.

Industrial Conditions and Requirements

All industrial applications are divided by Mr. Bower according to whether the power is taken from the shaft as a torsion load or by something like a belt or chain imposing a side pull. Another division depends upon whether continuous operation is required at constant speed and reasonably constant load, or at variable speeds and loads. Cooling and lubrication problems vary with these installations. Sometimes an 800-lb., 38-in. flywheel is used at a speed of 1000 r.p.m. Pumping a well or drilling with a cable tool imposes heavy loads during the up-stroke of the beam, and the load tends to speed up the engine during the down-stroke. Such a cycle may be completed in 60 revolutions of the engine, or 20 strokes per min., and engines are doing work like that 24 hr. per day the year round.

Ordinary power requirements listed by Mr. Bower are as follows:

Combines, 2 to 2½ hp. per ft. of cut.
Locomotives, 8 to 10 hp. per ton.
Fire pumps, 1 hp. for 10 gal. per min.
Arc welders, 14 to 18 hp. per 100 amp.
Shovels, 35 to 45 hp. for ⅝ cu. yd. and 80 to 100 hp. for 1¼ cu. yd.
Trucks, 30 hp. for ¾ ton to 125 hp. for 10-12 tons.

Economics of Automotive Diesels

Max Hofmann, a German Diesel-engine designer who secured part of his experience in Buenos Aires, where he had charge of the engineering department of Koerting Hermaños, Ltda., and who for several years has been engaged in Diesel research and design for the Waukesha Motor Co., gave a paper on the Economic Aspects of Diesel Engines. These engines can be made, he said, to replace almost any gasoline engine, with the advantages of steadier torque and lower cost of fuel, but it does not follow that all such installations would be economical.

Mr. Hofmann estimated the annual fuel cost of a passenger-car that is driven 15,000 miles at $178, while the cost of fuel for a similar car fitted with a Diesel engine might be $42. The total saving in fuel during six years would be $816, according to this estimate. However, if Diesel engines become common, the actual difference in fuel cost would be considerably less, and a Diesel engine could not be applied with advantage if the difference in cost between two engines were not much greater than the amount saved on fuel.

Conditions are different with a motorcoach that burns $1,500 worth of gasoline per year. With a Diesel engine, Mr. Hofmann estimates the fuel cost under the same conditions to be $417, resulting in a saving of $4,332 during a life of four years. He believes that it should be possible to provide a Diesel engine at a cost no more than $1,000 above that of the gasoline engine, which leaves a substantial saving in favor of the Diesel engine.

Smaller Diesel Engine Will Serve

Because of its better torque characteristics, Mr. Hofmann believes that a car can be driven satisfactorily by a Diesel engine having 80 to 85 per cent of the horsepower of a suitable gasoline engine. The radiator would be smaller in proportion, because the heat losses of the Diesel engine are less than of a gasoline engine. The Diesel engine possesses further advantages for aircraft work in reduction of fire hazard and weight of fuel for long flights and in elimination of radio interference.

Mr. Hofmann closed with the statement that only time and experience can show how long it will be before the Diesel engine can capture the markets in which its advantages sufficiently outweigh its higher cost. Quantity production, standardization and specialization in the manufacture of fuel-injection parts should make the cost of Diesel engines no more than 50 per cent higher than that of corresponding gasoline engines.

Engine Design and Accessories

Mr. Fisher, chief engineer of the Waukesha Motor Co., who was the third speaker, told of seeing a big motor-truck which rode on ten tires and sold for nearly $10,000. He lifted the hood, to find a device about the size of a sardine can which bore the designation of an air-cleaner. He asked the engineer why he placed a 28-cent air-cleaner on a vehicle like that and was told that happened only because the truck was finished late at night after the 5 and 10-cent store was closed.

To be sure, Mr. Fisher was corrected a little later in the evening by authoritative information that the air-cleaner actually cost 34 cents and was used because there was no room under the hood of the truck for both the engine and a certain air-cleaner that the engineer recommended, which was 99.95 per cent efficient. Mr. Fisher mentioned one engineer who recommended the procedure of laying out all the engine accessories inside the space available under the hood of a large motor-truck or motorcoach and then designing the engine to occupy the remaining space, if any.

The number of cylinders is one item that may be influenced by whim as well as engineering reasons, and it is not safe for the engine builder to try to dictate arbitrarily in the matter. When most tractors were made with one or two cylinders, a man from Iowa came to the factory in Waukesha to look for a four-cylinder engine for a tractor. Waukesha thought, but did not say, "Of all the crazy ideas!" The same man came back later for two engines, then for 50; since then he has used as many as 7000 four-cylinder engines per year for tractors.

Bearing Metals Compared

Structural features such as valve arrangement, desirability of cylinder liners, piston material and crankshaft design were also covered by Mr. Fisher. He spoke of the advantages of steel-backed bearings, in bonding between the metals; and of spun babbitt bearings in connecting-rods, because the structurally weak metal is thus made as thin as possible. Plastic-bronze bearings, composed of lead and copper, also have an advantage in their inability to transfer heat, thus lowering the maximum temperature.

Lubrication requirements were out-

Some folks just naturally like to regret things. Yes, there are some such people even in the S.A.E. They will fail to attend the 1930 Summer Meeting—

The 25th Anniversary Celebration of their Society—at French Lick Springs, Ind., May 25 to 29.

Memorial Day Week. That's easy to remember.

You, in all probability, are not a professional regretter. Therefore, decide to attend; and don't wait too long with sending in your reservations.

P.S.—The full details of the French Lick Springs Anniversary Meeting appear on page 416.

lined, with the statement that means for automatically heating the oil during light service in winter and cooling it in hot weather would be desirable. Accessories for this purpose have been developed but are not in production.

During the discussion which followed the presentation of the three papers, C. B. Jehnke, of Fairbanks, Morse & Co., said that plastic bronze has been used extensively in Diesel engines with generally, but not uniformly, good results. It is now being used successfully in piston-pin bearings carrying as much as 3000 lb. per sq. in. pressure, which would be too high for babbitt metal.

H. B. Miles, of the A. O. Smith Corp., argued that the engineer who designs the engine should include the accessories in the design, for the sake of unity. Mr. Bower and Mr. Fisher agreed that this would be desirable, but there are too many practical difficulties because of the different requirements of various purchasers.

In reply to a question, Mr. Fisher said that the maximum practicable piston speed of an engine is determined by blow-by. This increases very abruptly in some engines at a piston speed of 2800 or 3000 ft. per min. An engine can give good life in intermittent service so long as the piston speed is below that critical point, but the speed should be held to not much more than one-half that speed for 24-hr. service.

Radiators, steam and hopper cooling came in for comparison. The experience of a builder of concrete machinery indicates that requirements are far from uniform. He found that cement dust would find its way into radiators, set, and clog the water passages. Steam-cooling has proved satisfactory in some service where a little pinging of the engine is not objectionable.

Eugene Bouton, of the J. I. Case Co., raised the question of manufacturing steel-backed bearings. He was informed by Mr. Fisher that the surface to which the babbitt is attached must be rough, that the temperature of the steel is important, and that the most important trick of all is to introduce the babbitt immediately after the tinning, because oxidation enough will occur within a few seconds to interfere with the bonding.

Measuring Millionths of an Inch

Northwest Section Hears About High-Precision Gages and Two Types of Alloy Piston

TWO papers on pistons and one on high-precision gages were given at the meeting of the Northwest Section on March 7 at Seattle, with Robert S. Taylor in the chair.

The piston manufactured by the Ray Day Piston Co., of Detroit, was shown and explained by T. H. McLaughlin, who said that one of the main objects in designing this aluminum-alloy piston had been to minimize skirt distortion. To this end, the split skirt is heavily ribbed. A head expansion of 0.012 in. does not, he stated, affect the skirt, which, under maximum expansion conditions, would have to flex 0.003 in. Careful check-up on wear shows, asserted the speaker, that the skirt remains really round.

Mr. Van Buren, of the Tsun Gani Piston Co., of Tacoma, Wash., described his company's product, an alloy piston for replacement work.

Facts About Block Gages

Some very interesting facts about Johansson gages were stated by Faye White, of the Ford Motor Co., who, in outlining the history of that instrument, said that Carl Johansson, "the father of accuracy," is the only living man who has reduced anything definitely to millionths of an inch. When foreman of the Swedish Government Arsenal, he conceived the idea of measuring by means of solid blocks. The difficulty of this problem lay in producing, in steel, two flat surfaces that parallel each other perfectly. The first set of steel blocks meeting these conditions was made in 1897.

Having at last procured the right sort of steel, Johansson had to produce a finish so fine as to give a surface resembling quicksilver in appearance. Put together, two of these surfaces would resist a straight pull of 210 lb. per sq. in. at right angles to the surfaces. When a number of blocks thus made are built up together, a twist does not affect the measurement of the complete assembly more than 0.000002 in. per block.

World's Most Accurate Set

Three types of Johansson gages are now produced, being guaranteed to vary, respectively, not over 2, 4 and 8 millionths of an inch. They are intended for laboratory, inspection and working operations, respectively. There is now, in the Ford plant at Detroit, a laboratory set that is accurate to less than 0.000001 in., the only set of its accuracy in the world, according to Mr. White. With this set, 120,000 combinations—almost any that might be required—can be made. The holders handle blocks in combinations up to 80 in. in length, and 81 blocks are available to make the 120,000 different combinations. In a bar of 80 in. there are more than 100 joints. These gages are affected by temperature, their absolute accuracy being attained at 68 deg. fahr. The high cost of these sets is largely due to the fine finishing of the faces; these may be refinished without affecting their accuracy.

When Henry Ford contracted with Carl Johansson to come to America and direct the manufacture of his gages, the Swede agreed to teach the work of surfacing to one man. There is no written formula for this work and even Mr. Ford does not know how it is done. At the suggestion of the Johansson organization, the gages are turned in twice daily for inspection.

Mr. White explained and illustrated snap gages, go and no-go gages, and plug gages. All are made of non-magnetic steel, the same as the blocks. The speaker said that the Detroit laboratory set, before test use, is set and maintained at constant temperature for 24 hr. No one is permitted to approach within 5 ft. of the set during that time, because the warmth of the human body affects the temperature of the steel. An interesting observation made about these gages is to the effect that perfectly pure petroleum jelly will "eat off" the surface treated with it, so that the whole set must be refinished.

Zeppelin Review at Brookline

Dr. Hunsaker Addresses Joint Meeting of New England Section and M.I.T. Students

ADDRESSING an audience of several hundred, at the joint meeting of the Society's New England Section and M.I..T. Student Branch, held on March 12 at the North Hall, Brookline, Mass., Dr. Jerome C. Hunsaker created for his listeners a picture of lighter-than-air craft of today and tomorrow.

After reviewing the development of early Zeppelins in Germany, Dr. Hunsaker, who is vice-president of the Goodyear-Zeppelin Corp., of Akron, Ohio, gave a description of the new ships now being built by the company for the United States Navy. His talk was illustrated by a number of slides that excited considerable interest.

New Building Methods Adopted

Designed for a capacity of 6,500,000 cu. ft. of helium, the new Zeppelins are of duralumin construction throughout.

Your Society—
Your Celebration

S.A.E.

25th Anniversary
Summer Meeting

The Event of a Lifetime

French Lick Springs, Ind.
May 25 to 29, 1930

Details on Page 416

The speaker explained that the method of building the ships is new in some respects, the rings which form the transverse ship-frames being assembled individually on the dock floor and then hoisted into position. Each ring is built up of segments, and each segment in turn is assembled by a team of 12 men. As the American wage scale is approximately four times the corresponding German figure, this work had to be planned on a production basis, the men engaged in it operating on a bonus pay-plan.

After explaining in some detail the frame construction, Dr. Hunsaker directed the attention of the audience to another new feature of the ships now building. These aircraft will have the engines placed within the outside covering, the engines being mounted with their shafts transverse to the ship axis. The shaft ends will protrude through the hull and drive the propellers by means of bevel gears.

Water Recovery for Ballast

Among other things mentioned by the speaker was the condensation of the engine exhaust, to the end of furnishing water for ballast purposes, the weight of the water thus obtained corresponding to from 80 to 110 per cent of the liquid fuel burned in the engines. He also described the large dirigible dock at Akron, and gave some consideration to the importance of weather conditions in connection with Zeppelin operation, as well as to the construction of mooring masts and other equipment essential to lighter-than-air craft.

At the close of the meeting, those present were given an opportunity to inspect the aeronautical laboratory, the automotive-engine laboratory and the machine-tool laboratory.

Cosmetics for the Car

R. M. Smith Tells Canadian Section about Lacquer and Hints at Aladdin Miracle

ROUGE and lipstick, paint and powder were the provocative subjects that the members of the Canadian Section were invited to hear discussed at the monthly meeting at the Royal York Hotel, Toronto, on Wednesday night, March 15. But the address of the evening did not encompass these adventitious aids to feminine beauty. The speaker, R. M. Smith, Ontario manager of the Canada Paint Co., undertook to explain how cars get their chromatic pulchritude, or, more prosaically, Lacquer and Its Application to Automobile Bodies.

The Chairman, R. H. Combs, president and general manager of the Prest-O-Lite Storage Battery Co. of Canada, in introducing Mr. Smith, explained that he had been in the paint and varnish business himself, but it was a long cry since those days when 35 coats of paint were applied to carriage bodies and 27 of them sandpapered off.

In these days, said Mr. Smith, when cars have to be finished to match My Lady's dress or the brocaded shoe of the debutante; when lacquer has to have quick-drying properties for fast production, and when it must withstand the heat of summer suns for long hours outside a golf course, and the snow, rain, hail and frost of winter when parked outside the city club, the lacquer men have plenty of problems to keep them busy.

Illustrating the unparalleled growth of the lacquer industry in recent years, the speaker noted that in 1924 there were produced in the United States 3,590,000 gal. of lacquer; in 1925, 11,000,000 gal.; in 1926, 22,000,000 gal.; in 1927, 30,000,000 gal., and in 1928 no less than 47,500,000 gal. In Canada in 1928 the production was 1,200,000 gal.

Benefits to Car Industry

A large proportion of the production of cellulose lacquers, Mr. Smith said, was used by the automotive industry, and these lacquers had given to the industry accelerated production and conservation of floor space by eliminating the long-drawn-out process mentioned by the Chairman and the extended acreage needed for drying.

The speaker did not enter into any extended discussion of the technicalities of lacquer production but touched on the qualities of the various nitrated cottons used as a solid base and gave a practical demonstration of the solution of cotton in ethyl acetate. Production of lacquer which would have brilliance of color, correct flow, high gloss and tough film is determined by the balancing of the various solvents and non-solvents, cotton to gum and gum to oil, with the right amount of pigment as related to the cotton solution on which the lacquer is built.

In conclusion, Mr. Smith illustrated the various processes which the body of a car goes through before it finally emerges from the paint-shop as a finished product, and said that, with the public constantly clamoring for change, he wondered whether, in the future, someone may develop a finish that one might rub with a cloth, uttering a few magic words, and it would be black on Monday, gray on Tuesday and blue on Wednesday, as the owner's inclination might dictate.

The meeting was attended by 50 or 60 persons, including a number of representatives of the various paint and varnish interests in Ontario, and the discussion which followed the address related chiefly to durability of lacquers.

Serious Meeting on Light Subject

Hoosiers Hear Allen, Hyatt and Ricker on Headlight Research, Manufacture and Service

THE March 13 meeting of the Indiana Section was a headlight meeting, with the first paper by H. H. Allen of the Bureau of Standards, on Headlight Research, in which Mr. Allen gave a review of headlight testing and research methods of the Bureau. The paper was very complete and was illustrated with more than a score of lantern slides giving charts and other data brought out by some of the tests. The present trend of such testing is to find lights that really light up the road ahead, and the shoulder as well, in a way that will make for safe driving under present conditions.

F. W. Hyatt, of the Indiana Lamp Co., then presented a paper from the viewpoint of the lamp maker, in which the main ideals of modern automotive lights were first discussed, followed by a description of the Ryan lights made by the Indiana company. He made it evident that the headlight makers are at least following out what the research men say is necessary and are attempting to embody the principles to the best of their ability within the price limits and range of their wares.

Laws and Service Obsolete

Chester S. Ricker, president of Day-Nite, Inc., of Waukesha, Wis., and the first Chairman of the Indiana Section, then went at the subject from the viewpoint of the service man, who is faced by the fact that, no matter what the research men or the makers of lamps do this year or next year, more than 95 per cent of the cars on the road are at least one year old and many are in their tenth year of senility. The question is how to ensure the driver of any car adequate light to serve him well and safely on the congested highways.

The subject of Mr. Ricker's paper

was How Wisconsin Handles the Headlight Menace. No matter what the car or what type of lights it has, the author maintains that proper service will make those headlights adequate for safe driving at a fast rate. His company has developed a photometer that can be set up by light-testing service stations, that will at once give the correct reading of all points of the beam and make it possible to quickly and thoroughly service the lamps in case they need it.

Mr. Ricker brought out the fact that in State laws, and in the manner in which lights are infrequently serviced, we are trying to tackle 1930 highway congestion, with its 75-m.p.h. cars, with 25-m.p.h. head-lamps. As for the three or four mid-western States in the very heart of the motor kingdom, that own and drive one-fourth of all the cars in America but that still insist upon the dimming of lights in passing, the speaker seemed to imply that they are too benighted to discuss.

After the meeting proper adjourned, the members and guests went to Stout Field, of the Curtiss-Wright Flying Service, to witness demonstrations of night landing with Ryan lights and other landings made without landing-lights but using the flood-lighted field. Also, Mr. Ricker demonstrated the Day-Nite headlight-testing equipment.

Nominating Committee Chairman George Freers reported the following nominations for next year: Louis Schwitzer, Chairman; Bert Dingley, Vice-Chairman C. A. Trask, Treasurer; and Harlow Hyde, Secretary.

The Why of Design Changes

Knudsen Shows Oregon Section How Engineering Development Occurs Only To Meet Economic Needs

MUSIC by the "Springtime Syncopators," furnished by courtesy of the Benz Spring Co., added to the pleasure of the dinner which preceded the March 14 meeting of the Oregon Section at the Multnomah Hotel in Portland. Why Automotive Engineers Change the Mechanical Design of Automobiles was the subject presented to the meeting by William Ross Knudsen, of the Chevrolet Motor Co., whose experience in both manufacturing and service work was mentioned by Chairman A. R. Trombly in his introduction. Around the World with Knudsen might have been a more appropriate title for a talk of such broad scope as that which he gave.

Engineering was defined by Mr. Knudsen as the improvement of man's tools. The first engineer may have been the man who discovered the use of fire, but engineering became a specific problem only when men began to do serious thinking about their tools, and the useful development of mathematics did not occur until the late Middle Ages. Today a fair engineer may be working on hand shovels and wooden bridges and a good engineer on steam shovels and steel bridges, but the best engineers are studying astral physics and electronic emission.

Engineering development only follows needs, according to Mr. Knudsen, who said that carbureter problems would be worked on very much more intensively in this Country if the cost of fuel were as great here as it is in the countries of Europe.

Mr. Knudsen recalled that formerly 37 days were required to paint a Cadillac car. Painters told Charles F. Kettering that this was holding up the production of cars and that soon many square miles would be required for parking cars while the painting was being done. A consultation of experts resulted in a report that the time could be cut to 34 days. Mr. Kettering said that the painting should be done in 1 hr.

Requirements Bring Changes

While wandering through New York City, Mr. Kettering picked up a small Japanese article which he was told was lacquered, but he could not buy a quart of the lacquer. When he said he wanted it to paint an automobile, he was told that it dries too quickly. The development of lacquer finishes which resulted is an example of the way engineering meets real needs.

More power from a given quantity of fuel is one of the things that Mr. Knudsen says must come. Brakes also are due to have more development, and power-operated clutches will be demanded in the future. He also foresees the doom of the present type of transmission; more speed-ratios are not the answer, but electrical transmission may be. We may expect in the future to see a section of the radiator voted to cooling the crankcase oil.

Conditions in China and other countries where good roads do not exist may lead to the development of four-wheel-drive passenger-cars, while the existence of good roads elsewhere may lead to the elimination of chassis springs of the present form.

Engineering View of the Future

The practice of junking cars, which is now being actively encouraged by automobile manufacturers, is a serious economic waste. The average useful life of cars has been extended, according to Mr. Knudsen, from five years to seven years, and the future may see a development in cars made on the sectional-unit basis, so that one section can be removed at a time instead of scrapping a complete car. In this way, some of the units might give service for many years. The realization of such an idea would depend upon stabilizing our conception of beauty.

Tractor design, Mr. Knudsen predicts, will undergo a revolution in the near future. Russia holds the power that will cause this. The Soviet is embarking on the raising of wheat on a scale that has never been approached in North America. When the reaction reaches the American farmer, Mr. Knudsen believes that he will be obliged to meet the competition by the adoption of engineering methods that are now unknown to agriculture.

Prof. S. H. Graf, director of the engineering research department at Oregon State College, will give a discussion of the subject of Carburetion at the April meeting of the Section. He has been working for some time on a bulletin on the subject. It is expected that a meeting of the Section, possibly in connection with the Northwest Section, will be held at Longview, Wash., during the summer, at which the members will have an opportunity to see the lumber factories and logging operations of the Long Bell Lumber Co.

Baltimore Section Organized

APRIL 30 will usher in the first formal meeting of the Baltimore Section of the Society. This, it is understood, will be an aeronautic meeting and will, in all probability, be preceded by an inspection trip to one or two aircraft plants in the vicinity.

A series of organization lunches are being held each Friday by a number of members of the Society who are interested in the formation of a Baltimore Section, at which general plans for the new Section's activities are discussed. During the Baltimore Motorboat Trade Association's show, held March 8 to 15, the new Section occupied a booth in which a campaign for support and Section membership was carried on with considerable success. The temporary officers, who are also the nominees for office for the ensuing year, are as follows:

Chairman—G. O. Pooley, of the Chesapeake & Potomac Telephone Co.

Vice-Chairman—Norton L. Dods, of Calvert Motors Associates.

Secretary—Joseph Bassett, of the Yellow Cab Co.

Treasurer—Villor P. Williams, of the Automotive Corp. of America.

The Chairmen of the Standing Committees are:

Program Committee—Preston A. Petre, of the American Hammered Piston Ring Co.

Membership Committee—Edward W. Jahn, of the Consolidated Gas, Electric Light & Power Co.

Under the able leadership of Mr. Pooley, this Section gives promise of being one of the most active and successful of those recently organized.

Production Meeting at Buffalo

Methods from Plant Layout to Finished Product Described by Pierce-Arrow Works Manager

About 100 members of the Buffalo Section turned out to the regular monthly meeting on March 11 at the Hotel Statler to hear and see LeRoy F. Maurer, works manager of the Pierce-Arrow Motor Car Co., present a comprehensive paper on Production. The numerous lantern slides accompanying the paper made the address almost equal to an inspection trip to the plant. Mr. Maurer's presentation was most interesting and evoked a great many questions and much discussion.

The meeting opened with Secretary William E. John in the chair, in the absence of Chairman Gustaf Carvelli, who was on his honeymoon. After brief comments on Section membership and assistance of the members in Section Committee work, Mr. John asked Alban P. Carlson, chief draftsman of the Pierce-Arrow Motor Car Co., to preside during the presentation of the paper and over the discussion, in which Mr. John took an active part.

What It All Means

To how many, inquired Mr. Maurer, does the word "production" bring a picture of all the preliminary engineering, development and research work, planning of factories, methods, layout, final equipment, organization of personnel, and the start of production? Only the engineers who have been through this kind of work have a realization, he said, of what it all means. He then gave a chart outlining briefly the laying out or rearranging of a plant and the steps in production up to the point of shipping the new product.

Mr. Maurer then reviewed these various planning, purchasing and manufacturing steps, and illustrated the numerous production operations on major parts and bodies. He said that when the Studebaker Corp. obtained control of the company in August, 1928, it sent a group of men from its sales, engineering and manufacturing departments to Buffalo to cooperate with the Pierce-Arrow men in planning the production of a new eight-cylinder engine, developing a larger sales program, and revamping the manufacturing departments. After a survey had been made, it was decided to do this revamping in several steps, because of the work in process.

How this was accomplished was next described. Progressive movement of materials and parts in process was outlined and the manufacturing methods shown. The speaker took his hearers through the engine, assembling, body and other departments by means of word pictures and lantern slides, and concluded with the statement that the layouts described have reduced the cost of handling material, eliminated waste effort of the producer and enabled the workmen to spend the time necessary to produce a high-quality product without excessive cost.

Following his exposition, Mr. Maurer was called upon from the floor to give much more detailed information in answer to innumerable questions on specific points.

At the April meeting, scheduled for April 1, E. W. Dilg, chief engineer of the Evans Appliance Co., was to talk on Fuel-Moving Systems.

Service Exposed at Met Meeting

Two Hundred Members Inspect and Sup at Packard Station and Hear Three Papers

Thursday night, March 20, some 200 members and guests of the Metropolitan Section missed hearing Amos and Andy on the radio so as to enjoy the lively service meeting held at the new Packard super-service station in New York City.

Col. James W. Florida, Packard service manager, proved himself "the compleat host." Following a talk by Leon Dabo, distinguished American painter, and a paper on The Relationship of Car Design and Service, presented by Oscar A. Eskuche, service manager of the Warren-Nash Motor Corp., Col. Florida spoke on What a Modern Service Station Represents.

But first came the sightseeing. Arriving members were driven by personally conducted tours through the ultra-modern service station from cellar to roof in a fleet of Packard cars. Any who complained, after the ride up the double spiral ramp to the ninth floor in less than a minute, that they were too dizzy to see anything on the way down were given an opportunity to make the trip a second time. The passenger-car fleet was busy until Chairman Round's stentorian voice was heard issuing the supper call.

Although it was a "come-and-get-it" affair, an excellent buffet supper was served by the Maresi-Mazzetti Corp., which, as the Met Section *Booster* points out, are caterers and not Italian car manufacturers. Then, when the last chicken pie had disappeared, the meeting really came to order.

Why World Acclaims the French

Leon Dabo, the artist, was introduced first. A keen observer of the phenomenon of artistic and creative functioning, Mr. Dabo spoke of art and symmetry in car design and the contributions of the art world to the automotive industry. The first working plans for an automobile, he said, were made by Leonardo da Vinci, whose original drawings are now in the British Museum. Da Vinci also designed and experimented with gliders but, following a crash in which an apprentice was killed, further experiments were halted. Mr. Dabo brought out forcefully that industry depends upon the artist and the poet for creative ideas.

"Why does all the world pay tribute to the French?" asked the speaker. "For coal, iron, copper or lead? For machinery or agriculture? No indeed," he said, "it's because they create and export beautiful things; in a word, they design women's nighties! For the last three years," he continued, "beauty has been a most important element of motor-car design and finish and will unquestionably become increasingly essential as mechanical perfection is more nearly attained."

Saying that the intelligent use of color is a vital factor, too, Mr. Dabo laid

(*Continued on p.* 523)

Chronicle and Comment

A Representative Summer Meeting

IT IS GENERALLY felt that the Summer Meeting should represent a cross-section of the Society's activities. How well this ideal of a representative program will be fulfilled when the 1930 Summer Meeting convenes at French Lick next month can be learned from a reading of the plans for the meeting as outlined on page 416 of this issue of THE JOURNAL. No less than seven of the Professional Activities of the Society have undertaken to sponsor one or more sessions each, and the program will be rounded out and completed by a Research Session, a Standards Session, the semi-annual business meeting and two sessions of a general character that have been arranged by the Meetings Committee.

As announced in the March S.A.E. JOURNAL, a suitable celebration of the completion of the first 25 years of the Society's existence will be staged in conjunction with the Summer Meeting. Plans for this interesting and important event include a get-together dinner and an extensive exhibition portraying a quarter-century of progress, and the spirit of the Silver Anniversary will pervade the entire meeting.

Section Activity Benefits Recognized

THE PLACE that Sections activities occupy in the affairs of Society members is well evidenced by increase in the number and growth of Sections in different parts of the Country within the last year. Early last autumn Sections were organized in Pittsburgh, St. Louis and Wichita, as the result of repeated requests from members in those territories for the benefit of local Section meetings and activities. These Sections have experienced a very successful year so far and have contributed considerable to the fund of engineering knowledge through the various papers presented at their meetings.

About the first of this year a very live Section got under way with the formation of the Oregon Section by the group residing in Portland, which had originally been the second arm of the Northwest Section. About the same time a temporary organization was completed for the Twin-City Section, with headquarters in Minneapolis and St. Paul.

March witnessed the start of the Baltimore Section and the organization of a Section in Syracuse, to be known as the Syracuse Section; and as the April number of THE JOURNAL goes to press a request has been received for data regarding members and prospective members in the Tulsa, Okla., territory, where some ambitious members of the Society are endeavoring to arouse sufficient enthusiasm to carry on a Section in that town.

This brings the total number of Sections to 22.

The fact that in all of these cases the activity came from the members themselves, with no high-powered organization attempt on the part of the Society officers or staff, augurs well for their success.

Broad-Mindedness and Progress

SOME interesting questions are raised in a communication by C. G. Williams, a member of the Society, commenting on J. A. C. Warner's address at the Pittsburgh Section meeting on Section Membership Values and Opportunities, published in the January issue of the S.A.E. JOURNAL on p. 96. He writes in part:

> Mr. Warner is entirely correct in his paper only as it applies to members residing in the town where a Section is located; how about those members who reside at a distance from the meeting place of the Section to which they are assigned? Will such a member not generally be causing trouble for himself by attending meetings if he is not of the supervisory class in the firm for which he is working? Will the man who has to go 40 to 90 miles, or even 20 miles, and combat supervisory jealousy get enough from the average meeting to pay him for the trouble, in the light of present conditions of employment?
>
> The company hiring a man as a designer asks him to design something new, something out of the ordinary, and expects him to do it; yet that company will not allow him to have an hour off once a month to attend a meeting at which he might pick up some ideas worth thousands of dollars to the company. How can anyone expect a man to develop and hand out good ideas year after year without any stimulus other than the little help he gets from the supervisory engineers?

It seems almost unbelievable that, in this day of keen industrial competition and vaunted progress, any large proportion of companies employing automotive engineers, designers and draftsmen can fail to see the advantages of having such men keep as fully abreast of the developments in the automotive and allied fields as possible. Leading manufacturing companies make strenuous efforts to select new employes from the most likely young graduates from engineering schools, cull the technical literature for new ideas and the results of research and development work, and usually want their men to keep as well informed as possible in their line of work. Most likely such a policy accounts in part for the rapid progress of such companies.

Unenlightened supervisors may be responsible in some organizations for a less progressive attitude toward subordinates; and in some companies the higher executives may feel that the loss of one or two hours' work by an employe outweighs any possible benefit the company might derive from the contacts and information the minor engineer would get at engineering meetings.

Herein lies an opportunity for broader-minded chief engineers to do their companies and themselves a service by endeavoring to correct such an attitude of supervisors and foremen and of the officers and higher executives in their organizations.

Ambitious workers seeking to improve their status will gravitate by choice to the more progressive and liberal-minded institutions, to the further commercial and financial supremacy of such organizations at the disadvantage of the less enlightened companies

The Packard Diesel Aircraft-Engine

By L. M. Woolson[1]

Detroit Aeronautic Meeting Paper — *Illustrated with* **Photographs and Drawings**

THE PACKARD Diesel aircraft-engine is of the radial air-cooled type having nine cylinders with a bore of 4 13/16 in. and a stroke of 6 in., giving a displacement of approximately 980 cu. in. The engine is rated at 225 hp. at 1950 r.p.m., and weighs 510 lb.

This is the first description that has been released of the Diesel radial air-cooled engine concerning which a great deal of curiosity has been shown.

The mystery of the starting means is dispelled with the statement that a conventional type of starter used successfully with gasoline aircraft-engines is employed, supplemented with a special means for supplying heat to the fuel in below-zero temperatures.

The author describes the many radical features of design that resulted in producing an engine which operates at 2000 r.p.m. on domestic furnace oil, has a compression ratio of 16:1, air compression of 500 lb. per sq. in., compression temperature of 1000 deg. fahr., fuel pressure of the order of 6000 lb. per sq. in., develops 225 hp. at 1950 r.p.m. and weighs 2.26 lb. per rated horsepower.

Airplanes powered with this engine have been climbed to an altitude of well over 18,000 ft. without any special equipment.

The outside diameter of the engine is slightly over 45 in., and the engine is attached to the mounting ring with eight 3/8-in. bolts arranged on a bolt circle of 22-in. diameter. It will therefore be seen that, so far as its general characteristics with relation to size, weight and general arrangement are concerned, the engine does not differ radically from conventional gasoline aircraft-engines of a similar type, as can be seen in Figs. 1 and 2. This comparison, however, holds good only insofar as general external appearance is concerned, since the engine incorporates many constructional features never before employed in aircraft engines.

A casual inspection reveals a radical departure from current practice in that each cylinder is provided with only one valve, which serves for both inlet and exhaust; and the single rocker-arm box, which is slanted in the direction of the spiral of the slipstream, contributes considerably to the clean external appearance of the engine as shown in Fig. 3, and, what is more important, to its low parasitic drag.

As this engine operates on an entirely different principle than the gasoline engines used heretofore in aircraft, it is desirable before launching into a mechanical description to consider first in a general way the principles of operation of the Diesel-cycle as opposed to the Otto-cycle principle on which nearly all gasoline engines operate.

Diesel and Otto-Cycle Operation Compared

The real point of departure between the two systems of operation is the ignition system involved. In the gasoline engine an electric spark is depended upon to fire a combustible mixture of gasoline vapor and air, the ratio of which must be maintained within rather narrow limits to be fired by this method. Generally, a maximum variation of 2:1 is permissible; that is, the ratio of air to gasoline by weight may vary from about 10:1 to 20:1, and richer or leaner mixtures than these will fail to fire regularly in the gasoline-engine cylinders.

In the Diesel engine, air alone is introduced into the cylinders, instead of a mixture of air and fuel as in the gasoline engine, and this air is compressed into a much smaller space than is possible when

[1] M.S.A.E.—Aeronautical and research engineer, Packard Motor Car Co., Detroit.

FIG. 1—DIESEL ENGINE MOUNTED IN AN AIRPLANE

using a mixture of gasoline and air, which would spontaneously and prematurely detonate if compressed to this degree. The temperature of the air in the cylinder at the end of the compression stroke of a Diesel engine operating with a compression ratio of about 16:1 is approximately 1000 deg. fahr., which is far above the spontaneous-ignition temperature of the fuel used. Accordingly, when the fuel is injected in a highly atomized condition at some time previous to the piston reaching the end of its stroke, the fuel burns as it comes in contact with the highly heated air, and the greatly increased pressures resulting from the tremendous increase in temperature brought about by this combustion, acting on the pistons, drive the engine, as in the case of the gasoline engine.

Summing up, the differences between the Diesel and gasoline engines start with the fact that the gasoline engine requires a complicated electrical ignition system in order to fire the combustible mixture, whereas the Diesel engine generates its own heat to start combustion by means of highly compressed air. This brings about the necessity for injecting fuel in a well-atomized condition at the time that combustion is desired, and the quantities of fuel injected at this time control the amount of heat generated; that is, an infinitesimally small quantity of fuel will be burned just as efficiently in the Diesel engine as a full charge of fuel, whereas in the gasoline engine the mixture ratio must be kept reasonably constant and, if the supply of fuel is to be cut down for throttling purposes, the supply of air must be correspondingly reduced. It is this requirement in a gasoline engine that necessitates an accurate and sensitive fuel-and-air metering device known as the carbureter.

Fuel Requirements of Two Engine-Types

The fact that the air supply of a Diesel engine is compressed and its temperature raised to such a high degree permits the use of liquid fuels with a very high ignition temperature. These fuels correspond more nearly to the crude petroleum oil as it issues from the wells, and this fact accounts for the much lower cost of the Diesel fuel as compared with the highly refined gasoline needed for aircraft engines. Furthermore, it is necessary that gasoline have a very low initial boiling-point, since the gasoline must be intimately mixed with the air in the cylinder in order to be exploded by the electric spark, and this will happen only if most of the gasoline is vaporized at the time of ignition. This necessary quality in gasoline brings about the grave fire hazard in connection with its use, whereas the fuel oil used with Diesel engines is purposely controlled to ignite only at relatively high temperatures, thus ensuring absolute safety in handling.

The foregoing brief considerations of the distinctions between the gasoline and Diesel engines are cited to enable the reader to grasp what must be accomplished in building a light-weight Diesel aircraft-engine.

In the engine herein described, an advance that has been effected over previous Diesel practice consists in

FIG. 2—TEST PLANE POWERED WITH THE FIRST PACKARD DIESEL RADIAL AIR-COOLED ENGINE

Capt. L. M. Woolson (Left), Designer, and Walter Lees (Right), Test Pilot, Who Made a Non-Stop 1200-Mile Flight from Detroit to Miami, Fla., on March 9, 1930, in 10 Hr. 15 Min. with the Latest 225-Hp. Engine of This Type at a Total Cost of $8.50 for the Fuel Oil Consumed

the ability to extend the range of engine speeds possible with the Diesel cycle. Heretofore Diesel engines in stationary and marine service have been of the slow-speed type, running between 100 and 300 r.p.m. Even so-called high-speed Diesels of modern type have been limited to a maximum speed of about 1200 r.p.m. In the Packard Diesel aircraft-engine this speed has been increased to more than 2000 r.p.m., and this has been accomplished by an engine design that produces a turbulence never before approached in this type of engine. This method and the highly efficient and quick-acting fuel-pumps that had to be developed to go with it are the means that produce the accelerated commingling of the fuel and air which brings about this greatly increased engine-speed.

This successful high-speed operation has been attained with a corresponding increase in maximum cylinder-pressures, and it was early realized that a high-speed Diesel engine suitable for aircraft usage would entail these high pressures. This subject has been covered previously in some detail[2], so that further consideration at this time is unnecessary. Suffice to say that the structure of the engine is capable of withstanding maximum cylinder-pressures considerably in excess of 1200 lb. per sq. in.

Three basic principles of design are then to be considered in the description of the engine. First, the engine must be sufficiently strong to withstand maximum cylinder-pressures two to three times as great as those obtaining ordinarily in a gasoline aircraft-engine; secondly, a high degree of turbulence must be maintained in the cylinder to permit of all the fuel combining with all the oxygen present in the cylinder during the extremely short time allotted for combustion at high engine-speeds; and, thirdly, the fuel-pumps and nozzles must be designed to operate over a much wider range of speed than has heretofore been found practicable in Diesel engines.

In view of these three underlying basic principles of design, it seems desirable to describe the engine from each of these standpoints rather than merely to discuss each part of the engine without reference to its particular function in the general scheme.

How Light Weight Was Attained

The most interesting aspect of the design is undoubtedly a consideration of the features that have brought the weight of the engine down to practically the same level as that of gasoline aircraft-engines of equivalent power. Heretofore, even Diesel engines of the so-called light-weight modern type have weighed around 25 lb. per hp., whereas this engine weighs but one-tenth as much.

This great reduction in weight is essential for a successful Diesel aircraft-engine, and it is not surprising to find that radically new methods of construction have been employed to reach the desired objective. A review of the design will show that important weight economies have been secured by, first, the elimination of carbureters and magnetos, and, secondly, by an intensive simplification of design, as revealed in Figs. 4 and 5. Evidences of the latter are found in the one-piece crankcase construction of extremely light weight and the single-valve arrangement which automatically halves the number of parts required for valve operation as found in conventional gasoline engines.

[2] See S.A.E. JOURNAL, February, 1929, p. 175.

Novel Crankcase Design

The crankcase, which weighs only 34 lb., is unique, not only because it is of one piece, as in Fig. 6, thus dispensing with heavy flanges and bolts, but also in respect to the novel way in which the cylinders are fastened to it. Ordinarily, in a radial air-cooled aircraft engine, each cylinder is held to the crankcase by a multiplicity of studs screwed into the crankcase flange and projecting through the cylinder flange against which the retaining nuts seat. With this arrangement the tension stresses resulting from the explosion loads in the cylinders are carried through the crankcase walls to the crankshaft main-bearing anchorage. This involves fairly heavy crankcase construction even with a

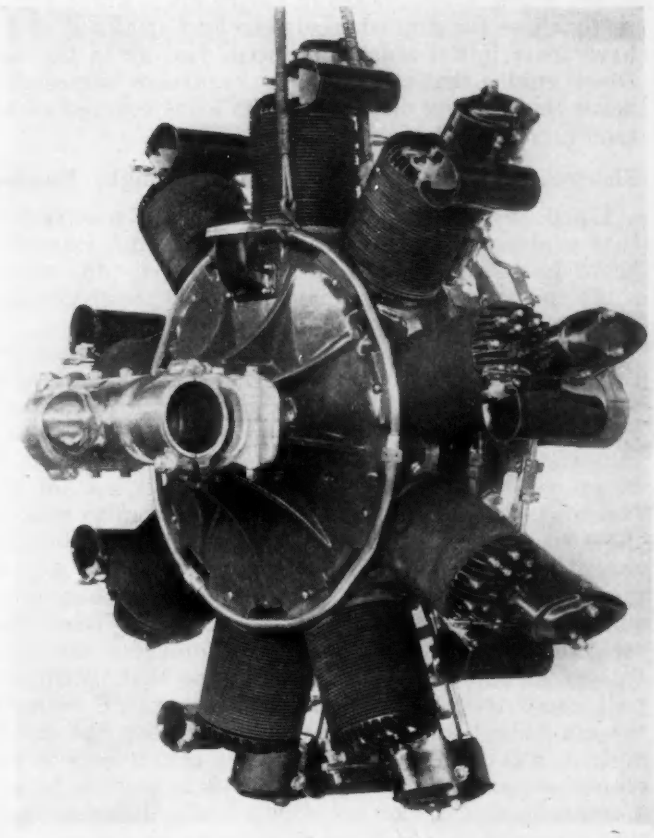


FIG. 3—ENGINE ASSEMBLED WITH PROPELLER HUB, SHOWING STREAMLINED ROCKER-ARM BOXES AND SHUTTER-VALVES IN AIR TUBES

The Air Shutters Are Connected to a Control Ring Operated in Conjunction with the Throttle by Means of a Cam for Idling Purposes, the Shutters Substantially Closing the Front Ports of the Cylinder-Heads so that All Air Is Drawn through the Exhaust Manifold

gasoline engine, but such structure applied to the Diesel principle would require the use of very thick sections, since the light alloys used in crankcase construction have poor resistance properties for this type of shock loading. In the Packard engine, two circular hoops of alloy steel encircle the cylinder flanges in contact with the crankcase at the front and rear of the engine, as is shown best in Fig. 3, and these hoops are contracted by means of sturdy turnbuckles so that an initial stress is set up in these hoops which exceeds by a wide margin the operating stress resulting from the cylinder explosions. Under this system the crankcase is subjected to

an initial compression which it is well adapted to resist. However, when the engine is running, these stresses are substantially reduced and at no time is it possible to transfer any tension loads from the cylinders to the crankcase.

Although the analogy is not strictly correct, a comparison may be made with an automobile wood wheel, representing conventional aircraft-engine crankcase construction on the one hand, and a wire wheel, representing the new Packard crankcase arrangement on the other hand. The latter construction has proved considerably lighter because the load is not transferred from the ground to the hub directly through the lower spokes, as is the case with the wood wheel, but is spread over a great many more spokes arranged in the upper quadrant of the wheel. Those spokes in a wire wheel which are directly above the ground receive no load at all but rather have their initial tension reduced, just as in the new Diesel engine that section of the crankcase immediately below the working cylinder has its loads reduced rather than increased at the time of explosion.

Shock-Absorbing Drive and Counterweight Damper

Equal in importance to the crankcase construction that enables a light structure to withstand extremely heavy loads are the arrangements whereby the crankshaft and propeller are protected from excessively high stresses.

The maximum cylinder-pressures are more than ten times as great as the average cylinder pressures during the working stroke. This would necessitate the pistons, connecting-rods, crankshaft and propeller being approximately ten times as strong as they would have to be to resist the average pressure were it not for the fact that effective measures have been taken to cushion these major parts of the engine from the shock-loading resulting from the high explosion-pressures. Advantage is taken of the fact that these peak explosion-pressures exist for a very short time in each cycle. The crankshaft counterweights and the propeller are both flexibly mounted on the crankshaft so that, when the peak pressures occur, a cushion is interposed between the crankshaft and those parts which have the maximum inertia or flywheel effect. Thus the stresses in the crankshaft are greatly reduced and it is possible to use a crankshaft of a size not substantially different than that employed in a corresponding gasoline engine (See Fig. 7). This feature of the design contributes considerably to the weight reduction as compared with previously built Diesels, which have all been characterized by extremely heavy crankshafts.

The counterweights, instead of being rigidly bolted to the crank cheeks, are pivoted on them and are located between powerful compression springs. With this arrangement, when the crankshaft is suddenly accelerated, the counterweights lag behind slightly so that the peak cylinder-pressure is expended before the counterweights are again solidly driven by the crankshaft.

Similarly, the propeller hub, instead of being splined or keyed to the crankshaft, is allowed to float on an extension of the crankshaft driving-end, and specially designed propeller-blade clamp-rings provided with integral driving-lugs receive the driving effort from a two-armed driving member splined to the crankshaft. Compressed on the extremity of each of these two arms are a pair of rubber blocks between which the propeller clamp-ring driving-lug is secured. These rubber blocks are confined in such a manner as to yield the desired elasticity. Here again a marked weight-saving is accomplished, since the propeller hub can be made of very light construction because it is completely cushioned from any driving shocks. While the elastic connection of the propeller to the crankshaft might in itself aggravate torsional vibration, the inherent damping or hysteresis of the rubber blocks, supplemented by the surface friction in the counterweight mounting, quickly and entirely smooths out the shaft rotation.

Cylinder Design with Single Valve

Before embarking on a detailed description of the engine, it may be desirable to discuss briefly the special features of the cylinder design which have resulted in a very light construction, each cylinder weighing only 11¾ lb. To begin with, it was recognized that the cooling problem of a Diesel cylinder was considerably simpler than that of a corresponding gasoline-engine cylinder, since the increased thermal efficiency of the Diesel is reflected in far lower heat losses to the cylinder-walls than is the case with the gasoline-engine cylinder. This fact justified a simple form of closed-end cylinder design in which the cylinder-head proper is formed integral with the cylinder barrel, as in Fig. 8, a construction which is not considered altogether satisfactory for gasoline engines because of the inferior cooling attained with this type of cylinder-head as contrasted with the much more bulky screwed-on aluminum type of head commonly used with gasoline engines.

Furthermore, the fact that only air is drawn into the cylinder on the intake stroke of the Diesel engine permits the novel use of a single valve for both inlet and exhaust purposes, and this contributes in a marked degree to the lightness of the cylinder itself, since the cylinder-head is weakened by only one port instead of two as in the conventional engine. The single-valve arrangement has been favored, not only on account of the general gain in simplicity and weight saving, but also in the interest of reliability, as the valve operates at a much lower temperature than the conventional exhaust valve due to the cooling effect of the incoming air passing over the same valve; moreover, the available time for opening and closing thereof can be utilized, thus saving wear and tear on the whole mechanism. Bolted to the top of each cylinder is a light aluminum cylinder-head carrying cooling fins and supporting the valve-operating mechanism as well as forming the combined inlet and exhaust port, as shown in Fig. 9.

High Turbulence Assures Complete Combustion

It may be well at this point to consider those features of the design that have contributed to maintaining a high degree of turbulence and also the reasons therefor. The fact should be realized that one of the main distinctions between a Diesel engine and a gasoline engine is the manner of assuring a homogeneous mixture of fuel and air. It is obvious that in either case such a mixture must be created if perfect combustion is to be secured in the extremely short time available, amounting to about 0.004 sec. at an engine speed of 1800 r.p.m. In a gasoline engine this mixing of fuel and air is accomplished in the carbureter, intake manifold, rotary distributor (if used) and finally in the cylinder itself during the intake and compression stroke.

In the Diesel engine no fuel is admitted into the cylinder until practically the instant that combustion is de-

sired, so it is obvious that in a high-speed Diesel special means must be provided to ensure complete and efficient combustion. This has been accomplished in the new aircraft-engine by giving the incoming air an extremely rapid whirling motion, so that at high speed the circulation of the air in the cylinder is at a rate which permits of one revolution of the mass of air around the circumference of the cylinder-bore in the time available for combustion. This high-velocity spiral motion is brought about by shaping the inlet port as a flattened venturi arranged tangentially to the cylinder-bore. The large diameter of the single valve not only assures a full volume of air to the cylinder but also offers little resistance to the speeded-up air-flow.

Looking at the cylinder from above, the port and valve locations are such that turbulence is created in a counterclockwise direction. Here again it will be noted that the single-valve arrangement lends itself particularly well to securing this high degree of turbulence, since it permits of a wider venturi passage being used than would be the case with a smaller valve, and this results in the ability to direct the air into the cylinder at the smallest angle to the horizontal.

In the preceding paragraph it has been shown how the air is introduced into the cylinder so that virtually all of the oxygen comes in contact with some part of the fuel spray, thus ensuring complete combustion; but such satisfactory results could not be obtained were it not for a finely atomized injection of the fuel, accurately controlled and timed.

Self-Contained Fuel-Pump and Nozzle Unit

The feature that probably contributes most to this phase of operation is the combination fuel-pump and nozzle unit. Heretofore the majority of solid-fuel-injection engines of the so-called high-speed type (maximum revolutions about 1200 r.p.m.) have been characterized by a multiple-pump unit mounted somewhere on the engine remote from the cylinder-heads in which the nozzles are located and connected to them by comparatively long capillary tubing. With such a system satisfactory high-speed operation is very difficult to obtain, for several reasons, the principal one being that enormous hydraulic pressures necessary for high-speed operation cause serious surges of pressure waves in the tubing which interfere with the correct timing of the fuel injection and also tend to make the engine run unevenly, since it is difficult to arrange the tubing to the various cylinders so that all of the tubes are of the same length. Another difficulty arises from the trapping of air in the capillary tubing, which air is difficult to expel and causes the engine to misfire. All of these troubles have been overcome with the fuel-injection system of the new engine, since the pump and nozzle are practically one unit, as shown in Fig. 10, with extremely short connecting passages between them.

A great deal of care has been given to the design of the moving parts of the fuel-injection system to reduce their inertia to the minimum, since at high speed extremely high accelerations in the order of 15,000 ft. per sec. per sec. are encountered.

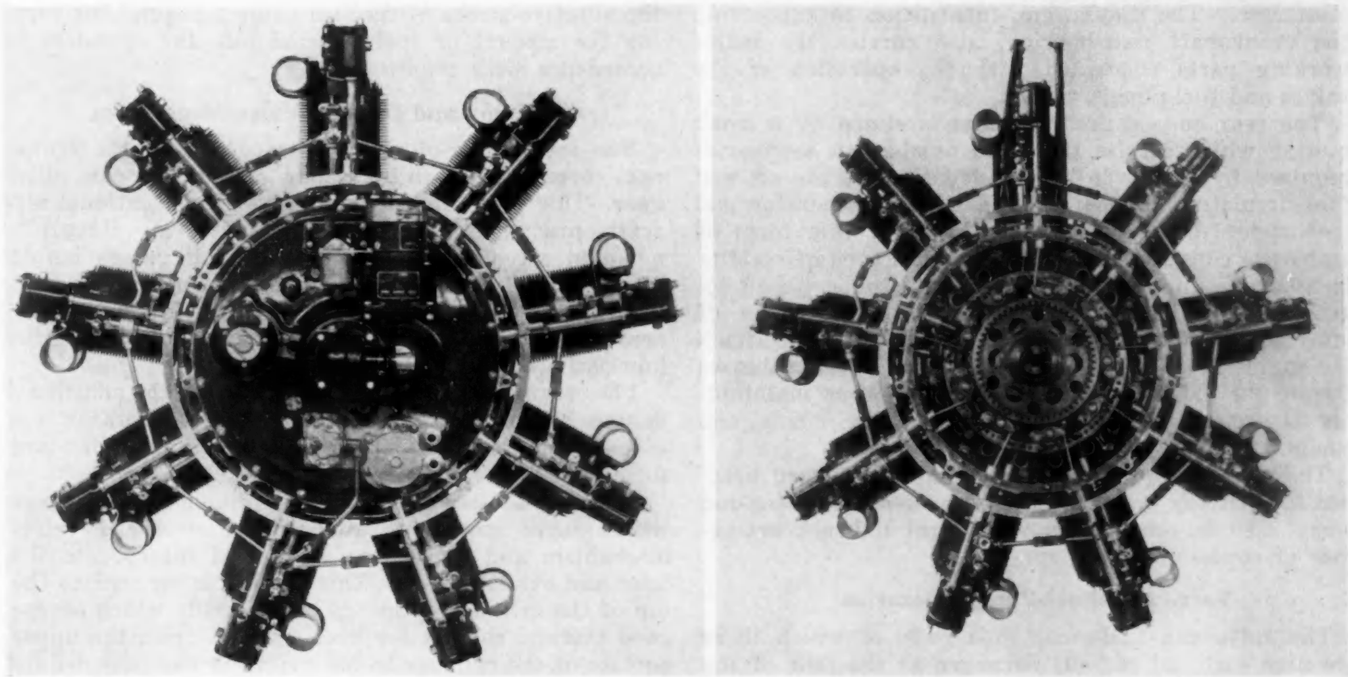


FIG. 4—REAR OF ENGINE WITH AND WITHOUT ACCESSORIES MOUNTED
Reduction of Weight Results from Elimination of Carbureters and Magnetos and by Intensive Simplification of Design

One-Piece Crankcase and Split Crankshaft

Having considered the major features of the design that distinguish the Packard Diesel from conventional gasoline aircraft-engines, it is believed that the reader will better understand the reasons for the many departures from customary aircraft-engine design as explained in the detailed description which follows:

The crankcase is a one-piece magnesium-alloy casting of rather large diameter, this casting supporting through the medium of a forged-steel container a deep-groove ball-bearing at the front end adapted to take both propeller thrust and radial load at this point (See

Fig. 5). A roller-bearing is mounted immediately ahead of the front crankshaft-cheek, as shown in Fig. 7, this bearing arrangement being quite orthodox.

The crankshaft is of the commonly used split type, the rear half being attached to the front half by means of a clamp bolt and key engaging the crankpin. The rear crankshaft-bearing is also of the roller-bearing type and is supported in a removable wall in the crankcase termed the diaphragm (See Fig. 5). This diaphragm is immediately in line with the rear cylinder-retaining hoop, just as the front crankcase integral wall is immediately in line with the front cylinder-retaining hoop. Thus these two walls receive the full compression of the retaining hoops, a close fit being maintained between the outside diameter of the diaphragm and the bored opening in the crankcase. Furthermore, a series of studs are used to locate the diaphragm in its position against the vertical faces of finished bosses in the crankcase. The diaphragm, in addition to supporting the crankshaft rear-bearing, also carries the major working parts concerned with the operation of the valves and fuel-pumps.

The rear end of the crankcase is closed by a cover casting which carries the small number of accessories required by this type of engine: namely, the oil and fuel-circulating pumps and the starter, generator and tachometer drives (See Fig. 4). With this form of crankcase construction the maximum degree of rigidity is assured, since there are no joints to be bolted together, which might also prove to be the source of lubricating-oil leaks. The hold-down bolts that attach the engine to the airplane mount engage integral bosses formed on the main crankcase-casting, thus maintaining the most direct connection between engine and mount.

The connecting-rod assembly follows standard practice in virtually every respect, a master connecting-rod being used in conjunction with eight link connecting-rods of conventional design.

Valve and Fuel-Pump Operation

The valve and fuel-pump push-rods, of which there are nine each, all radially arranged at the rear of the engine, are in turn operated by two cams which are formed integrally and each of which is provided with four lobes. These cams are driven at one-eighth engine speed in the direction opposite to the crankshaft rotation, a large internal gear being formed integrally with the cams and a compound idler-gear meshing with the cam and crankshaft gears respectively, as shown in Fig. 5. Both the single valve and fuel-pump of each cylinder are operated through the medium of rocker-arms, which contact with the respective cams and are supported on a common shaft anchored in the diaphragm and which also obtains a steady bearing in suitable bosses formed in the cover casting.

The pair of rocker-arms for each cylinder are located endwise between an integral shoulder on the shaft at the inner end and a shouldered bushing held in place by a cap-screw at the outer end. By these means all the rocker-arms can be located in place on the diaphragm as a bench assembly before the diaphragm is bolted in place inside the crankcase. Both the fuel-pump and valve rocker-arms contact with plungers fitted in forged duralumin guides which are radially arranged and bolted to finished surfaces on the outside of the crankcase.

Whereas the inner end of the air-valve push-rod seats in a spherical receptacle formed in the rocker-arm referred to, the inner end of the fuel-pump-operating push-rods fits in a specially formed groove or channel provided in the fuel rocker-arm. Furthermore, these fuel-pump push-rods are connected by linkage near their inner ends to a circular control-ring mounted in a groove on the diaphragm, the movement of which ring is controlled by an externally mounted lever connected to the pilot's control and offering the sole means of regulating the speed of the engine. The linkage referred to moves the inner end of the fuel push-rods in the rocker-arm groove, whereas the outer end of the push-rods is held in contact with the plunger. In the outer end of the plunger a tappet screw with lock-nut is fitted, this tappet screw contacting directly with the fuel-pump-operating plunger. It will be understood that the movement of the inner end of the push-rod alters the effective stroke of the fuel-pump plunger, thus varying the amount of fuel injected into the cylinders in accordance with requirements.

Oil-Pump and Outside Valve-Mechanism

The lubricating-oil pump is mounted on the crankcase cover and driven by a spur gear off the cam idler-gear. This pump follows more or less conventional aircraft practice, being provided with an integrally mounted screen through which the oil passes before reaching the pressure pump and a spring-operated relief-valve on the discharge side of the pressure pump arranged to maintain virtually constant pressure in the lubricating system.

The crankcase cover is provided with additional flanges conforming to standard S.A.E. generator, engine-starter and fuel-pump mountings, and a standard form of tachometer drive is provided.

The cylinder-heads are light aluminum-alloy castings which serve merely to support the overhead valve-mechanism and valve-stem guide and incorporate the inlet and exhaust ports. This casting is secured to the top of the cylinder by means of ten studs which assure good thermal contact for heat transfer from the upper surface of the cylinder to the radiating fins provided on the cylinder-head.

The valve-operating mechanism outside of the crankcase consists of a ball-end push-rod engaging a rocker-arm of conventional design mounted on a roller-bearing which oscillates on an eccentrically arranged shaft. This shaft is supported in bosses on the cylinder-head and is locked in place by a castellated nut. The adjustment of valve-tappet clearance is secured by the simple expedient of rotating the eccentric shaft the desired amount.

Each valve is fitted with 12 valve-springs of the multiple type used on previous models of Packard aircraft-engines (See Fig. 12), and as an additional precaution a small wire circlet engages the valve-stem above the valve-guide and prevents the valve dropping into the cylinder from any cause whatever. The purpose of the multiple-valve-spring arrangement is not only to assure the greatest possible security from the failure of individual valve-springs, but also practically to eliminate the probability of such failures, because the individual springs of this small diameter and light weight have very high periods of natural vibration, thus avoiding the danger of forced vibrations which experience has shown are largely responsible for valve-

spring failures. Furthermore, the small size of spring wire used has superior physical properties as compared with the larger sizes used with the more conventional form of valve-spring.

Pistons and Piston-Pins

The aluminum-alloy piston used is characterized by a peculiarly shaped head provided with an eccentrically located pocket, as seen in Fig. 13, designed to promote, in conjunction with the inlet-port and valve arrangement, a high degree of turbulence which is so largely responsible for the efficient operation of this engine at high speed. Two compression rings above the piston-pin and one oil-scraper ring below the pin are provided.

The piston-pin is of conventional construction and is allowed to float in both the piston bosses and the connecting-rod small-end bearing. Aluminum plugs are expanded into each end of the piston-pin to provide rubbing surfaces in contact with the cylinder-walls.

Detachable Fuel-Pump and Nozzle Assembly

One of the most interesting features of the engine is the fuel-pump and nozzle assembly. This constitutes a readily detachable and interchangeable unit which is bolted to a flange on the rear of the cylinder by means of two cap-screws. Fuel at low pressure is supplied to the screen housing and the pump plunger is operated by the adjustable tappet referred to previously. Aside from these external connections, the entire pump and nozzle represents a self-contained unit. There are many advantages favoring this construction, chief of which is the elimination of all high-pressure tubing between pump and nozzle and the avoidance of troubles due to this source, such as air pockets, after-dripping and variations in timing due to the compressibility of the liquid in the piping and the elasticity of the pipe itself under pressures as high as 6000 lb. per sq. in. as used in solid-fuel-injection systems.

The fuel-pump body consists of an alloy-steel forging machined all over and fitted with a bronze cylinder that is pressed in place, after which the cylinder-bore is finished by special equipment and methods developed to secure the extreme accuracy and high finish that are essential to this cylinder-bore. The pump plunger is formed of heat-treated steel and provided with a mushroom head which engages a T-slot in a cross-head or guide which in turn contacts with the fuel-pump tappet. A compression spring surrounds the pump cylinder and returns the pump plunger at the conclusion of its working stroke. Ports are provided in the fuel-pump cylinder through which the fuel enters after passing through a fine-mesh screen of such generous area that cleaning is not required for several hundred hours of operation. Clamped between the pump body and the nozzle body is a ball-check-valve assembly that permits the fuel to flow to the nozzle and prevents any gases from the combustion-chamber backing up into the fuel-pump cylinder.

The nozzle body is also an alloy-steel forging screwed to the fuel-pump body, the joint between the two being

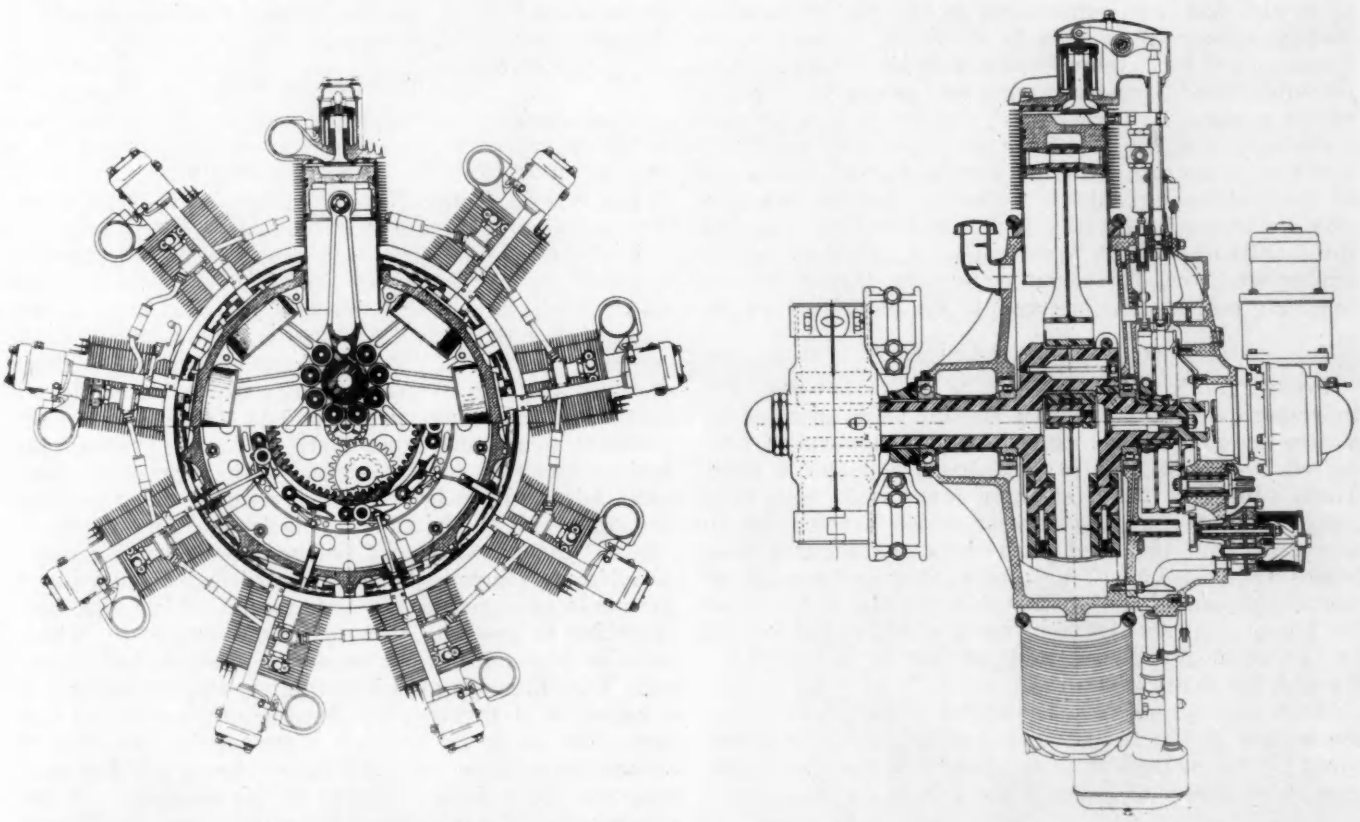


Fig. 5—Elevation Partly in Section and Vertical Longitudinal Cross-Section

Note Especially the Single Valve for Both Inlet and Exhaust, the Light One-Piece Crankcase Stiffened by Webs, the Alloy-Steel Rings Encircling the Cylinder Flanges To Take the Stress of the Explosion Pressure, and the Moderate Size of the Two-Piece Crankshaft, on Which the Counterweights and Propeller-Hub Are Flexibly Mounted To Cushion the Inertia Effects

lapped. The nozzle body is formed with an integral two-bolt flange which constitutes the means of attachment to the engine cylinder. The nozzle assembly is an independent unit which is screwed into the nozzle body and consists of a flared-end nozzle into which is seated a small poppet-valve fitted with a compression spring arranged to hold the valve seated not against the nozzle but against an independent adjustable screw-stop situated at the rear end of the nozzle body.

The nozzle valve is adjusted to be off of its seat a few thousandths of an inch, an arrangement which ensures excellent atomization for starting and entire freedom from any carbon-forming propensities. Furthermore, the fact that this valve is slightly "cracked" at all times assures prompt emission from the system of any air that may become trapped in the fuel. A certain amount of trouble has been experienced in the past with solid-fuel-injection systems due to air being trapped somewhere in the fuel system, which air, being readily compressible, would interfere with the proper functioning of the pumps.

These difficulties have been entirely overcome in the new aircraft-engine by using a rapid volume-circulation of the fuel throughout the system so that any air that may be trapped with the fuel is washed out through the return line to the tank, where it is vented to the atmosphere, and, furthermore, by painstaking care in the design of the fuel passages in the pump and nozzle.

Air Shutters on Front Cylinder-Ports

From Figs. 3, 8 and 9 it will be noted that each cylinder-head is provided with a shutter valve operated by a fore-and-aft connecting-rod, which in turn is connected by a ball-joint to the air-valve push-rod tube. These tubes are fitted at their inner ends with ball-jointed levers engaging sockets which are riveted to a control ring supported from the crankcase-mounting bosses (See Fig. 5). This control ring is operated by means of a cam in conjunction with the throttle, so that for idling purposes the front ports of the cylinder-head are substantially closed and all air is drawn back through the exhaust manifold.

While this system is not essential to the operation of the engine, it has been found that better idling is secured by this method, it being possible to run the engine steadily at speeds as low as 250 r.p.m.

Conventional Starter and Glow-Plugs Used

One of the major problems in connection with the development of this Diesel aircraft-engine has been that of starting. An aircraft engine presents a far more difficult problem in this respect than an engine built for stationary or marine service, in which fields the Diesel engine has been so extensively used in the past. The special requirements in connection with aircraft service are that the engine must start promptly in all conceivable operating temperatures, as in the case of an engine that has been standing for several days with a temperature of 10 deg. below zero. Furthermore, the starting mechanism must be of light weight and simple to operate.

A great deal of experimentation was carried on with various types of starter, such as the cartridge type using 12-gage shotgun shells, the compressed-air type and the various forms of field starter not carried in the airplane. However, it was finally concluded that the conventional type of inertia starter used so successfully with gasoline aircraft-engines offered the best solution. In the course of development work it was also conclusively proved that no Diesel engine could ever be started with reasonable expenditure of cranking power at below-zero temperatures without the aid of some external source of heat. Many different contrivances were tried and it was finally found necessary to develop an incandescent heating element or glow-plug to give the required heat. These glow-plugs are not required except at low temperatures but their presence in the engine offers no handicap to its ordinary operation and they will therefore normally be fitted, although in special cases they may be omitted and their place taken by blind plugs. With these glow-plugs, instantaneous starts are possible at any temperature at which it is possible to turn the engine over at all, and in respect to easy starting it can be claimed that this Diesel is superior to the gasoline engine.

Lubrication System

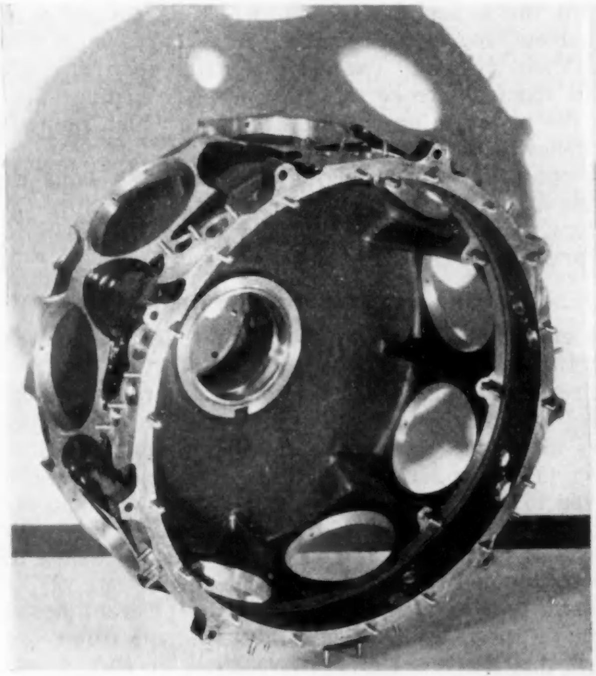
In general, the lubrication system does not differ radically from conventional aircraft-engine practice. A special effort has been made to simplify the system as much as possible and, in the interest of reliability, there are no oil pipes inside the engine nor are there any drilled passages in the crankcase itself. The system operates on the dry-sump principle, with an external oil-tank of suitable capacity in close proximity to the engine. A pipe leads from the bottom of this tank to a connection on the oil-pump housing, whence it flows through a screen of generous size which is readily accessible for cleaning purposes. The oil then enters the pressure pump and from there is forced through the main connection to the engine, with a pressure-relief valve adjusted to about 60 lb. per sq. in. for returning the excess oil to the tank. This lead to the engine is effected through a special hollow rocker-arm pin opposite No. 4 cylinder. At the inboard end of this pin a groove is arranged in the diaphragm, and a radial hole is drilled to lead the oil to a socket connection, which receives one end of what appears to be a hollow dumb-bell. The other end of this swinging connection engages a socket in a forged ring floating on the hub of the cam. The oil is led through a groove in this ring to several holes in the cam and thence through drilled passages to the hollow extension of the rear half of the crankshaft. The purpose of the dumb-bell connection is to allow the oil-ring to float concentrically on the cam without being restrained in any direction by the connecting member.

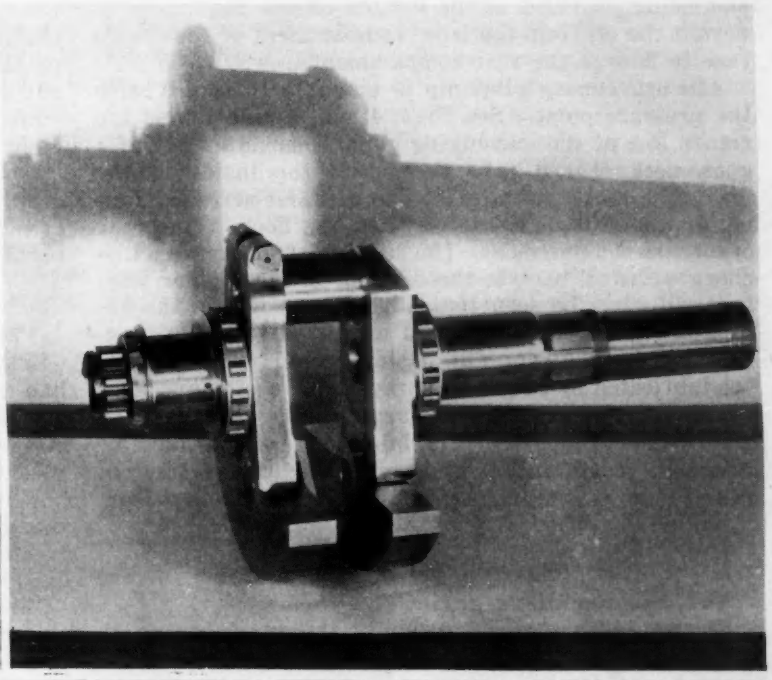
The rear crankshaft-cheek is drilled in line with a hole communicating with the interior of the crankpin, which is bored out for lightness and to act as an oil reservoir. A hole is drilled in the crankpin for lubricating the connecting-rod bearing, which is formed of two flanged bushings mounted end to end with a small space between them. Oil flows through this space into slots machined in the master connecting-rod big-end bore and thence through small holes drilled at an angle to bring oil under pressure to the link-rod-pin bushings.

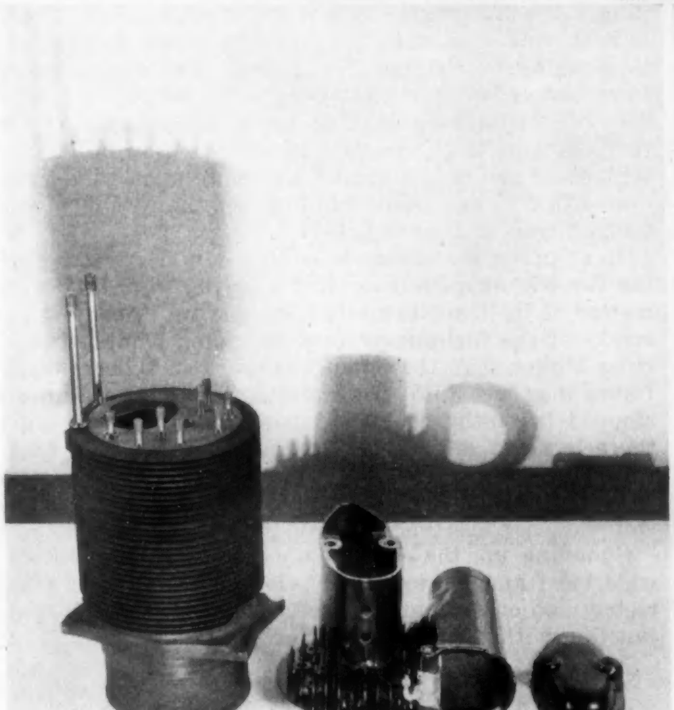
Both crank cheeks are also drilled to provide oil passages to the counterweight-pin bushings. How these counterweights are allowed to swing slightly on the crank cheeks to provide a cushioning effect for the powerful engine impulses is described elsewhere.

Returning now to a consideration of the diaphragm oil-passages, the main radial feed hole which supplies

oil to the oil-ring referred to is extended to meet a groove surrounding the rear roller-bearing liner. This circular groove distributes oil through eight other radially drilled passages to each of the hollow rocker-arm shafts. These shafts in turn are drilled radially with small holes to provide pressure lubrication for both the fuel and valve rocker-arms. The valve rocker-arm is further provided with a small drilled passage in one of the webs to lead oil to the rocker-arm roller-pin, and this pin is drilled with several radial holes to lubricate







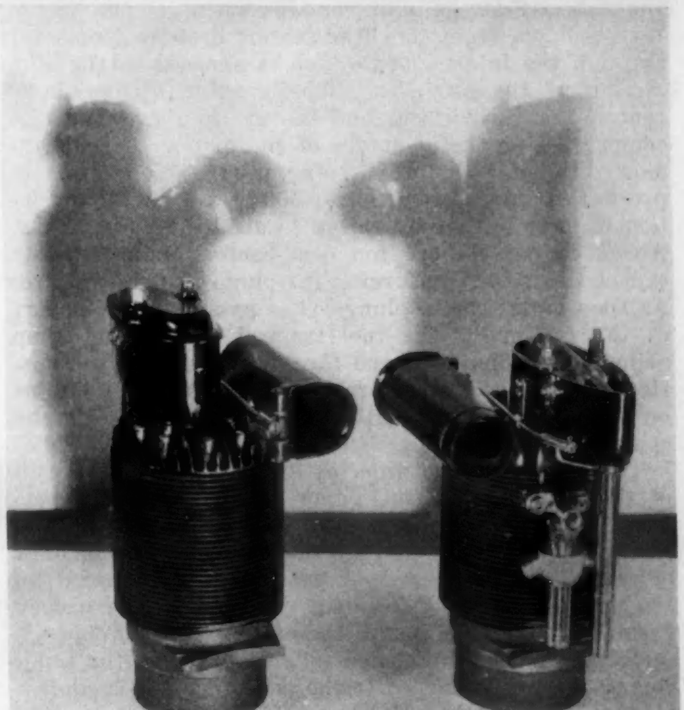


FIG. 6—ONE-PIECE LIGHT-ALLOY CRANKCASE

The Cylinders Are Held in Place in This Crankcase by Two Alloy-Steel Rings That Encircle the Cylinder Flanges and Are Tightened by Means of Turnbuckles

FIG. 7—TWO-PIECE CRANKSHAFT WITH FLEXIBLY MOUNTED COUNTERWEIGHTS

FIG. 8—CYLINDER AND CYLINDER-HEAD CARRYING OVAL SUPPORT AND HOUSING FOR THE VALVE-OPERATING MECHANISM AND INLET AND EXHAUST PORT TUBE

FIG. 9—FRONT AND BACK OF CYLINDERS ASSEMBLED WITH HEADS, SHOWING ROCKER-ARM, AIR-SHUTTER OPERATING MECHANISM, AND COMBINATION FUEL-PUMP AND NOZZLE UNIT

the roller bushing. The crankcase cover is also drilled with various passages so that positive lubrication is supplied to the various accessory shafts and their bearings.

On the return circuit, the oil thrown from the various bearings gathers in the bottom of the crankcase, a slot being provided at the bottom of the diaphragm to permit the oil from the front compartment of the crankcase to flow to the rear compartment.

The scavenging oil-pump is mounted in a unit with the pressure pump (See Figs. 4 and 5, right), and the return line of the scavenging pump consists merely of a goose-neck shaped tube flanged to the inside of the crankcase cover and attached to a coarse-screened funnel arranged to suck the oil from the floor of the rear crankcase compartment. The scavenging pump then discharges the oil back to the oil tank in the regular way.

It will thus be seen that all bearings within the engine are positively lubricated except that the antifriction bearings, piston-pin bushings and cylinder-walls are lubricated by splash or spray in the customary way.

The external valve-rocker-arm bearings are of the roller-bearing type and are lubricated periodically by means of a pressure gun, such lubrication being required only at extended intervals, as every 25 or 50 hr. of engine operation.

Operation of the Engine

The operation of the engine is as follows:

Starting with a consideration of the intake stroke, it will be found that the single valve has been open during the exhaust stroke and remains open as the piston travels down from top dead-center, drawing fresh air through the intake port, which is exposed to the slipstream of the propeller. Shortly after bottom dead-center, the valve closes and the air in the cylinder is compressed on the up-stroke of the piston. A compression ratio of about 16:1 being used, the air is compressed to a pressure of about 500 lb. per sq. in. and its temperature is thereby raised to about 1000 deg. fahr. About 45 deg. before top dead-center, the fuel-pump tappet starts to rise, forcing the pump plunger upward. As soon as the pump plunger has passed the inlet port of the fuel-pump, the fuel trapped in the fuel-pump cylinder is compressed and forced out through the nozzle in a finely atomized spray which immediately ignites on coming in contact with the superheated air in the cylinder.

The amount of fuel injected depends upon the length of the stroke of the fuel-pump plunger above the cut-off position, that is, the point at which the inlet port to the fuel-pump is covered by the plunger. The amount of stroke above this cut-off position is determined by the position of the fuel-pump push-rod in the groove formed in the fuel-pump rocker-arm, which depends upon the position of the control ring carrying the small connecting-rods attached to the push-rods. This control ring is rotated through a small arc by means of a tapered roller engaging in a slotted yoke which is riveted to the control ring. The tapered roller is mounted on a short lever which is splined to the control shaft, and this shaft is journaled to the shaft to which the pilot's throttle-control is connected.

As aforesaid, the fuel injection starts about 45 deg. before top dead-center and continues until the piston is almost at top dead-center, thus allowing the pressure to rise in the cylinder at a comparatively slow rate until a maximum pressure of about 1200 lb. per sq. in. at wide-open throttle is reached. When the piston passes top dead-center, the gases expand in the cylinder until the single valve opens approximately 45 deg. before the piston reaches bottom dead-center. The products of combustion are then forced out through the valve and through the exhaust manifold, which is connected to the rear opening of the combined inlet and exhaust port on the cylinder-head. The valve remains open throughout the exhaust stroke and, of course, continues open while the piston is on the intake stroke which immediately follows.

The operation of the engine is exactly the same regardless of how much fuel is being introduced into the cylinders, except that for very slow idling the fresh-air ports are almost closed by the shutters.

Starting and Stopping the Engine

The engine is started by means of the familiar type of inertia starter used commonly with all types of gasoline aircraft-engines. This starter incorporates a small flywheel which is rotated through a system of gearing at very high speed by means of either a hand-crank or an electric motor and, when sufficient energy has been imparted to the flywheel, a dog-type clutch is manually engaged with the crankshaft, resulting in the rapid cranking of the engine for a few seconds necessary to dissipate the energy stored up in the small flywheel.

With this arrangement, practically instantaneous starting is possible at all times and the only difference between starting this Diesel aircraft-engine and the ordinary gasoline-engine is that the throttle on the Diesel is held wide open while the engine is being cranked and no priming or choking is required. The engine starts immediately on its regular supply of fuel oil, no special fuel or preparatory heating being necessary. At low temperatures it is essential to use the glow-plugs, and with their use it is a simple matter to start the engine even after it has been standing for many hours at a temperature of zero or below.

In stopping the engine it is merely necessary to close the throttle completely against a spring stop, this extra motion of the throttle mechanism serving to restrict the stroke of the fuel-pumps until the pump plunger barely rides higher than the pump inlet-port and consequently forces no fuel into the nozzle. The engine can be stopped instantly, no matter how hot it may be, since there is never any danger of the engine kicking backward as with the gasoline engine stopped in this way. It is therefore never necessary to shut the fuel off when stopping, nor are there any switches to operate.

Summing up, the engine is started with the throttle wide open and is stopped by closing the throttle completely; no other controls are used except those in conjunction with the inertia starter.

Types of Fuel

This Diesel engine has been run with many different kinds of fuel and apparently, so far as the engine itself is concerned, the fuel specifications can be extremely broad. The fuel generally used and found highly satisfactory has been domestic furnace-oil as used in oil heating-plants for residences and costing about 9 cents per gal. This particular grade of fuel oil is a refined product having a gravity of approximately 37 deg. Baumé, or a specific gravity of about 0.84, and is almost entirely free from dirt and impurities and well suited

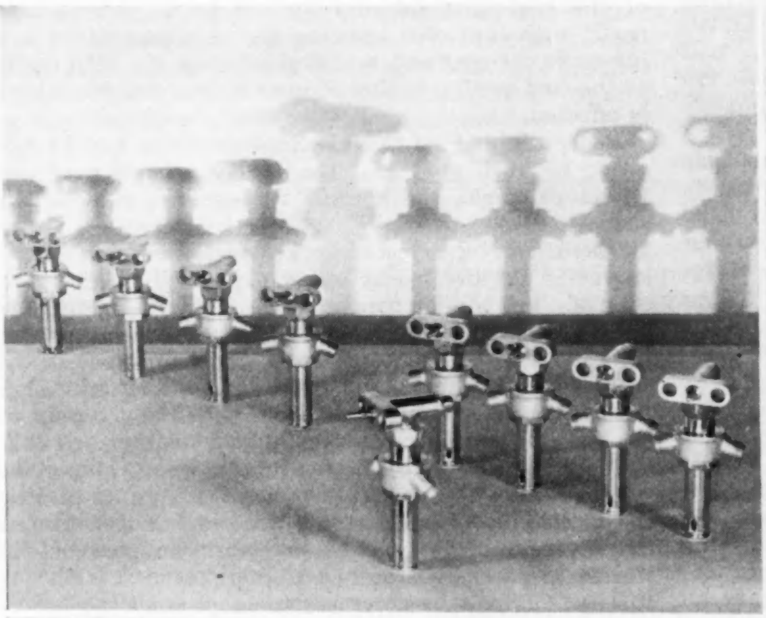
for aviation use, having a sufficiently low pour-point so as to flow readily under any temperature conditions so far encountered in experimental flying, such as —20 deg. fahr.

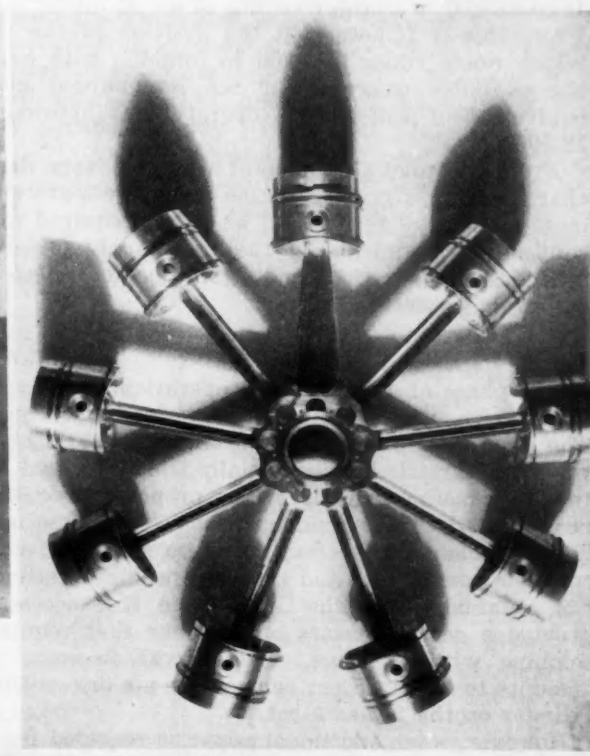
A question that has been asked repeatedly is, "Will the engine run on gasoline?" The answer is "Yes," but such practice is not recommended under any circumstances whatsoever. In the first place, all the advantage of the Diesel engine so far as fire hazard is concerned is lost, and, in the second place, gasoline has no lubricating qualities, whereas fuel oil has a considerable degree of "oiliness," hence the fuel-pump plungers and cylinders work very satisfactorily with fuel oil but not nearly so well with gasoline unless a certain amount of lubricating oil is added to the gasoline; and, lastly, less power is secured with gasoline than with fuel oil owing to the fact that the fuel-pumps have been proportioned to deal with the former fuel, the heat value of which is approximately 23 per cent in excess of that of gasoline on a volumetric basis.

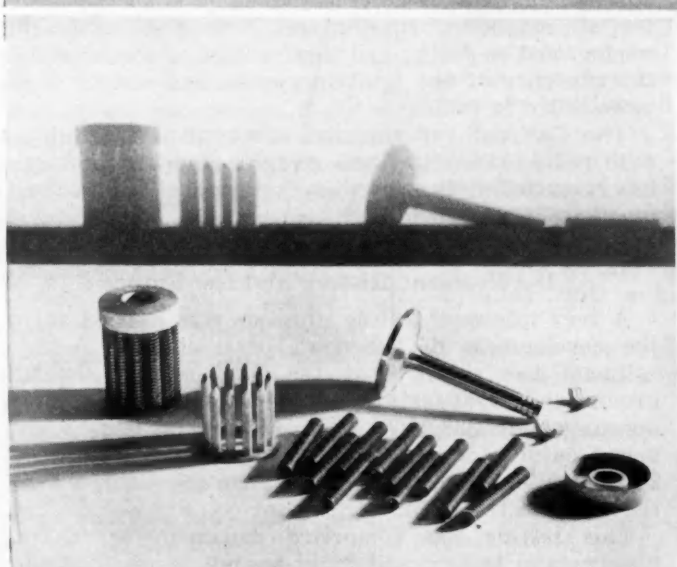
Operation at Altitude

It has frequently been prophesied that Diesel aircraft-engines would not be able to operate in an airplane at great altitudes without using some form of preheater or supercharger or both. Experience with the Packard Diesel proves such theories entirely erroneous, as both the Waco and Stinson airplanes have climbed to well over 18,000 ft. with the engine functioning in a normal manner without special equipment of any kind.

In connection with the altitude operation of the engine, one rather interesting condition has been found. Normally, when a plane is climbing with a gasoline engine, the engine revolutions will drop somewhat as higher altitudes are reached and, although the car-







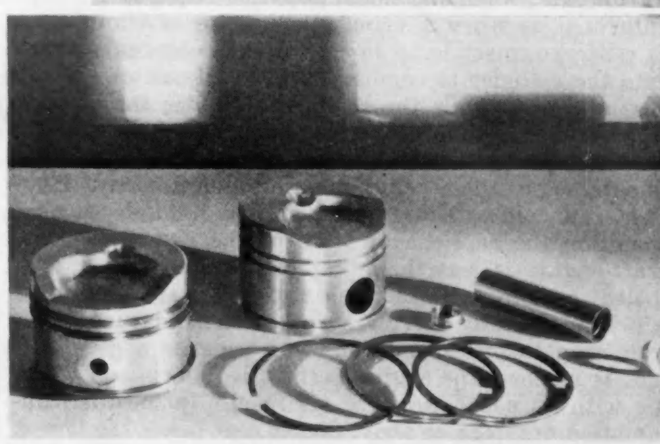


Fig. 10—Combination Fuel-Pump and Nozzle Units

Fig. 11—Connecting-Rod and Piston Assembly

Fig. 12—Valve and Multiple-Type Valve-Spring

Fig. 13—Pistons, Rings and Piston-Pin

bureters can be leaned out by means of the altitude adjustment to bring the revolutions up slightly, nevertheless, for any fixed position of the throttle, the engine speed will decrease with altitude. With the Diesel engine, however, assuming that soon after the take-off the throttle was closed somewhat to cruising position, it was found that the engine increased in speed as the plane climbed, instead of decreasing as in the case of the gasoline engine.

This is a rather interesting phenomenon and is responsible for an extra degree of fuel economy under flying conditions, since the engine automatically adjusts itself to burn efficiently whatever fuel is being injected. The increase in speed with altitude under set throttled conditions is due to the fact that a predetermined amount of fuel is injected into each cylinder and this fuel needs for its complete combustion a certain weight of oxygen. Now, the density of the air naturally decreases with altitude so that a given weight of oxygen is contained in a larger volume of air at higher altitude. From this it follows that the position of the throttle which would cause the fuel to combine with only half the available oxygen near sea level would give the equivalent of full-throttle operation at approximately 18,000 ft.

From the pilot's standpoint this is a very desirable characteristic, since the engine tends always to give the most economical result, and he is not required to make continual adjustments in the fuel supply for varying altitudes, as is necessary to get the most efficient result from a gasoline engine.

Reserve Power

One phase of Diesel-engine operation which requires explanation is the so-called "overloading" condition. The maximum power of a gasoline engine is obtained when the throttle is substantially wide open and a mixture of gasoline and air of the proper degree of richness is used. The maximum power of a Diesel engine, however, cannot be defined quite so simply. To secure complete combustion and the low specific fuel-consumption obtainable with the Diesel cycle, it is necessary to provide a certain excess of air over that required to combine with the fuel. This excess in many cases amounts to about 25 per cent of the air drawn into the cylinder on the intake stroke.

However, when additional power is required for brief intervals, as when a plane takes off or is climbing, it is quite permissible to inject an extra amount of fuel into the cylinder to combine with nearly all of this excess air; and, while the combustion under these conditions is not as complete as normally and results in the engine smoking somewhat, a considerable gain in power is obtained at the sacrifice of some fuel economy. However, it should be noted that even under this overloaded condition the fuel consumption of the new Diesel aircraft-engine is less than that of the majority of air-cooled gasoline aircraft-engines, the carbureters of which are usually set for a rather rich mixture under wide-open throttle conditions. As soon as a safe altitude is reached, the engine is throttled down, and working with its usual excess of air results in the fuel consumption dropping to about 20 per cent below the lowest it is possible to obtain with the gasoline aircraft-engine.

The advantages claimed for the Packard Diesel aircraft-engine can be summarized under the following headings:

Advantages of the New Engine

Reliability.—The engine is inherently far more reliable than the gasoline engine because (*a*) the electrical ignition system is eliminated, and (*b*) a separate fuel-injection means is applied to each cylinder, in contrast to the use of a single carbureter feeding several cylinders in a gasoline engine. This means that in the Diesel engine each cylinder operates independently of the others and the failure of any one fuel-pump would not affect the other cylinders.

Fire Hazard.—Thousands of hours of ground and flight testing have conclusively proved that it is impossible to accidentally ignite the fuel oil used in the engine. It is virtually essential to atomize this fuel into a very fine spray before it can be ignited at all, and at no time has it been possible to start a fire under any conditions simulating the result of an airplane crash or accidental breakage of the fuel line in flight.

Reduced Fuel Consumption.—A conservative estimate of the fuel-consumption reduction in weight as compared with that of a gasoline engine represents a saving of 20 per cent and, due to the higher specific gravity of the fuel used, a saving of over 30 per cent by volume is effected.

Reduction in Fuel Costs.—Because of the much lower grade of fuel used and the higher efficiency of the Diesel principle, the specific fuel-cost is considerably reduced.

Operation Not Affected by Temperature.—The Diesel engine is not affected by either abnormally high or excessively low air-temperatures, as is the case with the gasoline engine. On the one hand, there is no tendency for the Diesel engine to detonate or preignite as in the case of the gasoline engine, nor, on the other hand, has it any characteristics comparable with the icing-up of the gasoline-engine carbureter in cold weather and failure of the engine to accelerate properly after a long glide.

Elimination of Radio Interference.—The fact that no electrical ignition equipment is used in the operation of the engine removes one of the most troublesome obstacles to extensive radio use in airplanes. With the gasoline engine it is necessary to adopt shielding means for all magnetos, spark-plugs, high and low-tension wiring, and so forth; and these shielding means reduce the efficiency of the ignition system and render it far more liable to failure.

The Packard experimental cabin plane is equipped with radio transmitter and receiver, and in this way it has been definitely proved during extensive flight-testing that, in regard to both transmission and reception, there is complete absence of any interference.

Development History and the Future

A very intensive testing program was carried out in the development of the new Diesel engine. A close estimate has shown that the total of experimental ground and flight-testing amounted to an equivalent of approximately 338,000 hp-hr., which represents a sufficient output for an average plane to fly a distance of 250,000 miles, or somewhat more than the distance from the earth to the moon.

This testing has comprised dynamometer testing, torque-stand testing and flight-testing in two different kinds of airplane, a Stinson Detroiter six-place cabin plane and a Waco three-place open-cockpit plane. Ground-testing on individual engines has been carried up to 500

(*Concluded on p.* 449)

What the Public Wants in Airplanes

By W. B. Stout[1]

Chicago Section Paper

SINCE the investment banker has poured some $760,000,000 into aviation recently, he has placed some load on the shoulders of the aircraft industry. I do not know of any industry that has ever started into which as much money has been poured as quickly as it has into the aviation industry. In some respects this is a detriment to the industry because we all know that the investment bankers are not putting their money into the industry for nothing. I am very much afraid that the only people who will reap any benefit from the industry as it stands today will be the investment bankers. I cannot see where some of the people who are now manufacturing airplanes and airplane accessories can ever hope to make much profit, because they have a very heavy load to carry when they have to pay some of the bills that these investment bankers will ask them to pay. The banker has finished his job of furnishing the wherewithal in the matter of cash. Now the industry must produce constructively from this vast investment. The danger is one of too much money. Experiments are likely to be made on too large a scale, and the size of mistakes in proportion. A man with $10,000 will experiment as cheaply as he can to conserve every dollar and his mistakes will be small. The man with $1,000,000 will make just as many mistakes but his will be on a larger scale, each one 100 times more expensive. For this reason the big firms can less afford to make mistakes than can the small firms, though first analysis would seem otherwise.

The new industry includes airplane and engine design, sales, servicing, publicity, advertising, export and what not. Which is the most logical way to turn in this vast experiment? We all know that aviation is coming, but how? To date we have revised the Wright biplane by better engines and better aerodynamics, but we have not changed the materials. We are still largely building kites, because kites are cheaper to build than other forms. I visited the Ford Motor Co.'s airplane factory in Detroit recently and was impressed more forcefully than at any previous time with what must have been the cost of installing the equipment in that factory. Two immense structural-steel wing-jigs must have cost not less than $10,000 each to install. Other equipment includes fuselage jigs and fuselage-frame jigs, all very precisely built of metal, not slapped together in a haphazard way; they are all built to very close limits. That is the reason, I think, why at present more all-metal planes are not being built; they cost too much money and people do not feel that they can go into it so deeply.

Is it not time that we realized that at this stage of development the great cost is sales? Adding $1,000 to the first cost of an airplane is much cheaper if we can save $1,000 in the sales resistance, for we build up volume so much quicker, and volume manufacture is the only permanent way of low-cost production. In producing a new airplane design, sales is the first item to have in mind today, even ahead of performance to some extent.

Better engines and better aerodynamics have improved airplanes; materials are unchanged.

Sales resistance is more important than performance. Selling the eye is more important than selling the ear.

The public is not competent to say what it wants in an airplane. Therefore the engineer must design what should be bought for safety's sake and sell the product on performance, appearance appeal, comfort, price and service.

Design the airplane that gives the utmost in safety and transportation comfort first and then learn how to produce it cheaply.

Appearance is the prime requisite in a private airplane. While necessities of design give airplanes proportions of pleasing appearance, repetition of distance or areas, color spots or accents or a pleasing eye-line will enhance appearance appeal.

Future powerplants will be entirely enclosed and air-cooled.

Airplane Selling Methods

Sales departments cannot force on the public something that it does not want. A high-pressure sewing-machine salesman cannot be sent around to back doors to shove in an airplane while his assistant rings the front doorbell to get the lady of the house front and center. Firms that have tried the motor-car method of sales and distribution and "pep" meetings of dealers have come out of the sessions sadder but wiser. Something new is here in aviation and something new is required to move this new product. The method itself must visualize something new to the prospect or he will not be convinced. When we talk to a man to convince him, the sound goes in his ear, but he must translate this sound into a picture before the idea can go to his brain through the eye, which it does over the optic nerve, not from the nerves of the ear.

In reading an advertisement, the eye makes a picture of that advertisement and sends it to the brain over the optic nerve. The brain then makes sense or nonsense out of the advertisement and takes it or rejects it, as the case may be. Talk or printed word, therefore, has to be translated and loses its force and authority. If the eye can be immediately sold on a product without

[1] M.S.A.E.—President, Stout Air Services, Inc., Dearborn, Mich.

recourse to spoken word or the printed page, the mental decision is immediate and final. I mention this bit of psychology as a defense of the term "visualize" as a sales fundamental.

In the matter of airlines and airliners, I shall let others speak, for these firms have money and established figures to give them a definite check on what they want and must have in equipment. I want to confine this paper to the private owner who will, I believe, be the great backbone of the airplane business within a few years.

What Does the Public Want?

What kind of an airplane does the public want? Of course we know what they think they want, especially those who do not fly. As a matter of fact, the public is not competent to say what it does want. Therefore we can pay little attention to what the public tells us it wants. We must design for what the people should have for their own safety and then make them want it, by performance, appearance, appeal, comfort, price and service. Confidence must be the backbone of the campaign. Art must be the eye appeal of the design, and then the sales plan must appeal to the type of man whose purse fits the cost of the product.

You cannot sell a $15,000 airplane to pilots, for they cannot afford it. They want $1,500 machines. However, I believe that, if rightly worked, the market for a really safe $15,000 airplane is greater right now than the market for a $1,500 one, but not for long. The wealthy man is the one most interested today, but the eventual buyer is the man on the street. If, however, we start out to build cheap airplanes, we shall get nowhere, for the buyer has no confidence in them. What we must do first is to build the airplane that he wants, one that sacrifices nothing to give the buyer the utmost in safety and transportation comfort, and learn how to produce cheaply after we have first solved the problem. No airplane as yet built solves the problem. This step is the vital next one. The next move is purely and simply an engineering one. The solution is up to brains and the slide rule, with a large modicum of art, the science of eye appeal, added.

W. B. STOUT

When industry took over the airplane from the Army and Navy three years ago, almost nothing had been done in the way of improvement since the war except in detail. Better instruments, design formulas, air-cooled cylinders, metals and details had been developed, but the flying craft was the same as when the war ended. Committees of experts can design only compromises. Within two years after commercial money entered the field, we had brakes on the landing-gears. These were widened to twice the tread. A wheel instead of a skid was put on the rear. Pilots were enclosed and able to discard the armor of a Goliath on a cold day and move freely in a warm glass room in comfort and with visibility. Monoplanes and thick wings increased load capacity and lessened the length of landing runs. Metal construction was adopted and developed. Really streamlined fuselages came into being. Today our 1000-lb. freight vehicles can run away from the pursuit airplanes of two years ago and with one-third less horsepower.

Creating What the Public Will Buy

We have, however, a vast mass of invaluable material developing in the industry which can now be put to work for the buyer to create an airplane that he will buy. The first requirement of the coming private airplane, or any other machine in fact, is appearance. The public will resist being sold an airplane that looks like an accident going somewhere to happen. They want something that looks like a vehicle. In this day and age we do not need to start out with homely contraptions as the motor-car business did, as we now know the fundamentals of art well enough to make things good looking. Good engineering is good art always.

Motor-cars became good looking by a process of cut-and-try development during the years. Airplanes are generally good looking by the proportions wished on them by the necessities of design. They can be made much more appealing however. Repetition of distance in the design is one method. Repetition of areas is perhaps more subtle. Color spots and accents mean much. Get a proper eye-line that starts the eye at the front and carries it by a pleasing curve to the rear. Dynamic symmetry even is applicable to this new industry to obtain good looks. If someone looks at a new airplane and says immediately "I want it," we have accomplished more than the engineer who calculated the excellent performance. If the inside of the craft be Swiss cheese and the wings tea lead, this part is easy to solve and is a known art, once we have the appeal in the design.

If we go down the street and see a beautiful looking automobile, we do not think of what is under the hood, in the axle or anywhere else. We accept as very nearly a proved fact that the engine is there and the chassis and the rear axle are well designed. If it is a beautiful car on the outside, it is something we want. I do not believe any one of us would hesitate to buy one of those cars today. If we can do the same thing with an airplane, we shall have made considerable progress. We are beginning to know engineering as applied to airplanes and aerodynamics; we are beginning to have some basic facts to work on. The next move is to clothe those hard-headed engineering facts in more beauty, more comfort and more pleasure for the average passenger. I fly around the Country so much that it probably is becoming an old story to me, but the trip here from Detroit is just about as long as I want to take in the average airplane today, sitting there in one position. Of course, in our Ford three-engine craft we can wander from one end of the cabin to the other, but our limits are small; we must provide something that will give the passenger more comfort.

Airplanes must appeal in a way they do not now. They must visualize strength and reliability of structure as well as speed; comfort and roominess as well as power. Sell the eye and we have sold the pocketbook. The prospect is now interested and we have the rest to show him.

The Safety Factor

Next is safety. The buyer wants to know what kind of a field the airplane has from which to operate, how long is required to take off, how fast the airplane climbs and in how short a distance it lands. Perhaps, however, he does not even know what he wants in performance. We must tell him and show the result in the airplane, which must be able to fly in calm air, hands off. It must come out of a dive hands off and assume its proper gliding angle. It should not spin of itself, and when forcibly spun should come out quickly. At least 50 hp. per person should be provided and 100 is better. The airplane should cruise at more than 100 m.p.h. on not exceeding 60 per cent of the total horsepower. Visibility must be better in all machines. The pilot must have a clear range ahead in all weather at all flying angles and also to the rear on top. Approaching a field in a 45 to 90-deg. bank, the pilot should be able at all times to see the spot where he aims to land. This favors the low-wing monoplane considerably. In a high-wing airplane, the pilot should be forward of the wing, which means a big machine or a new seating arrangement.

Some day we shall take away one control, the rudder or the aileron, and have it automatic; bank the airplane and it turns; the rudder is automatic; no sideslips or fish-tailing, but we can stall it in slower and kill speed that way better.

Landing-gear must have twice the spring action that it has now; 1 ft. for small airplanes, 3 ft. or more for big ones. We should be able to stall down to a landing without hurting the machine.

The new airplane wheel developed by the Goodyear company and fitted with the Musselmann tire is all tire, with virtually no wheel and a very small hub. A 22 x 10-in. wheel has a hub about 4 in. in diameter, a tire 22 in. in diameter, and a 10-in. sidewall, carrying a pressure of 8 to 10 lb. Some were on the Fokker single-engine airplane at the Chicago municipal airport last Saturday; they were, I think, 36 x 18-in. tires and were carrying 10-lb. pressure. The landing strut had no air-check in it at all; it came right down on the wheel. We got a very perceptible bounce, but no hard, quick jar as with the present landing-gear. We were very much pleased with them, and we think that is the coming tire for landing-gears. Instead of having just a single landing-gear, the number will depend on the size of the aircraft, and we may have two wheels in tandem or perhaps two on an axle and one forward under the nose, or something of that kind.

Instead of 50 hr. flying being required before a man is ready to be sent off alone across country, 25 hr. should be made ample by mechanical improvements making flying and distance judging easier.

Powerplants will eventually be entirely enclosed and air-cooled of course. Cabins will be higher and wider and better streamlined. Upholstery and fitments will be adapted to the comfort of the owner. Freak machines will come, such as flying wings with everything inside the flying surfaces, a type I have consistently argued for since 1917. Tail-first machines will have their vogue, allowing of a better engine placement and better visibility in small craft. Landings will be easier to make, perhaps, and safer, and the structure lighter. Better protection in case of crash is also a thing the public wants to have.

We cannot be satisfied with the present airplane. We are forced to move on and quickly. Every added device for safety and comfort should be available now. Who will first produce the plane of appeal? Whoever does will establish an industry greater than that of any motor-car company.

THE DISCUSSION

CHAIRMAN D. P. BARNARD, 4TH[2]:—I surely would enjoy hearing Mr. Cook's comments upon the latest Bellanca creation that has received so much newspaper publicity. Some acquaintances at the Bellanca factory have given me to understand that the craft will perform but I honestly think it is probably one of the homeliest things I have seen created, at least in recent years.

I was much interested in Mr. Stout's assumption in the paper that air-cooling is the best method for the airplanes of the future. I have had the idea that direct air-cooling probably is not. It seems to me to be a rather difficult way to cool an engine, especially if fineness of design is required to get performance from the airplane. We see craft like the big Ford three-engine airplane, for instance, a beautiful job in every respect, with polished wing and fuselage surfaces, fitted with big engines out in front, shaped like a hub and spokes, and in addition two tremendous dishpan affairs, that must be pushed through the air by brute force, hung under each wing. My opinion has been that considerable cleaning up of the design of an airplane by the use of indirect cooling should be possible. Frankly, I have a soft spot in my heart for the Army's idea of Prestone cooling, which makes possible the use of very small radiators and the carrying of very little weight of cooling fluid and possibly, under some conditions, no radiator at all, simply making sure that the jackets of the engine are of sufficient capacity and present a moderate area to the airstream.

One of the principal difficulties with direct cooling, I understand, is getting the heat, not away from the cylinder as a whole, but away from one or two local spots in each cylinder where most of the heat must be dissipated. That results in spreading the air-cooled engine out until it is almost an aerodynamic impossibility, especially where the engine becomes of considerable size in proportion to its power output.

P. E. COOK[3]:—Answering your first question relative to the Bellanca airplane here in Chicago, we shall see many freaks and many funny things before we get

[2] M.S.A.E.—Research automotive engineer, Standard Oil Co. of Indiana, Whiting, Ind.

[3] Vice-president and general manager, Stout Engineering Laboratories, Dearborn, Mich., who presented the paper in the author's absence and answered questions in the discussion.

through with this development. We cannot afford, today, not to take notice of any of them or overlook one of them. We must study them and look at them. Some of these look more like nightmares than anything else. Inventors seem to submit all their problems to us. We have designs submitted that are all wings and some with no wings at all.

The Airplane Powerplant of the Future

We do not know what the powerplant of the future will be. It may be something that we can place entirely out of sight in the wing. Some day somebody will find the solution. The radial engine seems to be the best that we have now, but what the future engine will be I do not think anybody knows.

If we can dispense with the engine entirely we shall make some progress. Why cannot we put the gas to work in some other way of propulsion, blowing it out of the trailing edge of the wing, for instance, creating the propulsive force in some way as we are doing with the propeller today? As far as the powerplant is concerned, we have certain things in view now. People ask us about this or that powerplant, and we tell them at the laboratory that we do not know; we shall use what we have today and hunt for something else tomorrow.

FRED A. CORNELL[4]:—I have heard Mr. Stout say that air is the proper cooling medium in the air, as water is on the water. Do you know whether he is experimenting with any other cooling media?

MR. COOK:—We are not doing any experimenting with power devices in the laboratory at present but may eventually. We have some other problems that are taking up most of our time now, and we have sidetracked the power question for a while. I have heard Mr. Stout make the statement that putting an air-cooled engine in a motorboat is just as sensible as putting a water-cooled engine in an airplane.

Air or Liquid-Cooling

ROBERT E. WILSON[5]:—Certain considerations regarding the selection of a cooling medium have not been given the study they deserve, I think. In this age of cutting corners, direct air-cooling sounds like making a big advance over indirect cooling, and at first thought transferring heat directly from the walls of an engine through metal fins to the air would seem much more efficient than passing it through the cylinder wall into a flowing stream of fluid and then through another thin metal wall into the air.

As a matter of fact, however, direct air-cooling has two serious drawbacks. Actually, cast iron is not a very good conductor of heat and cannot carry heat for any distance nearly as effectively as a stream of fluid. It also lacks flexibility in that the cooling around certain points, such as exhaust ports, from which especially large quantities of heat must be dissipated cannot be greatly increased, whereas, with indirect cooling the flow of liquid past such points can be increased to take care of almost any quantity of heat. Again, in transferring the heat to the air, the inherent advantage of air-cooling in starting with higher temperatures is far more than counterbalanced by the fact that the use of fins, particularly cast-iron fins, necessarily gives much higher head-resistance per unit of exposed surface than does the honeycomb structure of a radiator to which heat can be carried by a liquid.

From the standpoint of preventing localized hot-spots in the engine and getting the necessary cooling with the minimum of wind resistance, both of which are very important in airplane engines, I believe that indirect cooling has a great fundamental advantage over direct air-cooling. The magnitude of this advantage tends, however, to be obscured by the fact that water is far from being the ideal liquid for this purpose in the case of airplane engines, though its availability, cheapness, high heat-capacity and great fluidity make it a very satisfactory fluid for cooling automobile engines, except where its freezing point interferes.

D. P. BARNARD, 4TH

I believe that the advantages of liquid-cooling have been somewhat obscured by the fact that almost all attempts to use liquid-cooling have been confined to the use of water. In designing the ideal indirect cooling-system for airplane engines, a fluid that can be heated to a fairly high temperature without causing boiling or deterioration, is obviously desirable, because the higher the temperature of the fluid going to the radiator is, the smaller is the surface required to dissipate its heat to the air. Furthermore, the greater the temperature range is through which the liquid can be cooled, the smaller is the quantity of liquid that has to be circulated to carry away a given quantity of heat, other factors being equal. Water is limited in both of these respects by the fact that it boils at 212 deg. fahr. or lower, depending on the altitude, and therefore the ordinary temperature-range between the liquid going to and returning from the radiator under summer conditions is probably only from about 180 down to 120 deg., a temperature drop of about 60 deg. fahr., while the average temperature-difference between water in the radiator and the air under summer conditions is only about 80 deg.

If, however, we employ a cooling fluid that can be used up to a temperature of 300 deg., the engine-walls could still be kept cool enough for all practical purposes and yet the temperature drop between the liquid in the radiator and the air would be greatly increased and the temperature range over which the fluid was cooled and heated would also increase, thus decreasing the amount of circulation required. I understand that the Army Air Corps has found that certain mixtures of ethylene glycol and water can operate under such temperature conditions and that the net result is both increased efficiency and decreased head-resistance.

From the standpoint of those who are working on developing a satisfactory fuel for the airplane engine, the difference between the localized high temperatures in some parts of an air-cooled engine and the uniform

[4] M.S.A.E.—Secretary, C. G. Spring & Bumper Co., Detroit.

[5] M.S.A.E.—Assistant to the vice-president in charge of manufacturing, Standard Oil Co. of Indiana, Chicago.

and moderately high temperature in a liquid-cooled engine makes a tremendous difference in the ease of avoiding detonation and in the range of fuels that are available for an engine of a given high compression. I think we must all pay some attention to this because cutting down the fuel load is principally accomplished by high compression, yet we cannot do that if we are to have localized hot-spots that greatly increase the tendency to detonate.

F. M. SAY[6]:—What is the freezing-point?

MR. WILSON:—I believe the pure liquid freezes at about 0 deg. fahr., but the freezing-points of the mixtures with water that are ordinarily employed are far below this, because ethylene glycol is commonly used as an antifreeze agent for automobiles.

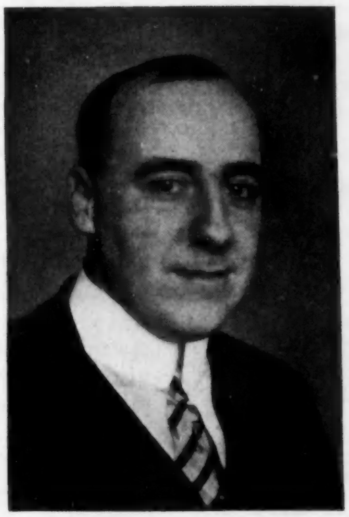
MR. SAY:—Would it freeze at a lower or higher point than water?

MR. WILSON:—Much lower than water.

CHAIRMAN BARNARD:—The lower limit is not determined so much by the freezing-point as by the point at which the fluid becomes so thick that it is a little difficult to circulate, and that is far below —40 deg. fahr. We can regulate the temperature at which it will boil just by the addition or elimination of a few per cent of moisture.

A. J. LABAIE[7]:—At the Bureau of Standards the congealing-point was found to be —60 deg. fahr.

CHAIRMAN BARNARD:—Pure ethylene glycol has an appreciable viscosity even at ordinary room-temperature. Probably at very low temperatures this would be too much for the pump system on an engine to handle. In trying to start a cold engine, we might have too much load on the driving mechanism of the circulating pump even before getting down to the freezing-point of —60 deg. fahr. I understand that Prestone is being used in its diluted form for cooling, and certainly no danger of getting excessive viscosity down to —40 deg. should be encountered.



ROBERT E. WILSON

Noise Elimination and Design Beauty

R. E. WILKIN[8]:—I should like to look at this situation from another angle. The paper mentioned several things that are being done or should be done to add to the comfort of the passenger. Probably the most important thing, as I see it, was left out; that is, the noise of the powerplant. Not long ago I rode in an airplane of probably the poorest design from that particular angle, and in 2½ hr. I had a severe headache. Has any way been devised whereby we can insulate the passengers' cabin from this noise? We know that we cannot do it entirely by muffling the engine, because considerable noise comes from the propeller, but I believe that would be one very necessary step to be taken before people who generally enjoy trips in an airplane would use them regularly. If we had to hear that clatter in the Pullman car, I am sure we would not plan any pleasure trips by rail from Chicago to New York City.

Are we in a position now to say what is a beautiful airplane? We probably thought in 1915 that the 1916-model automobile was the most beautiful car we had ever seen, and we know that if we place a 1916 automobile alongside of the present design, it would be about the homeliest. Cannot airplanes be designed first to be most efficient aerodynamically and then create around them the proper idea of beauty?

MR. COOK:—The only fundamental of beauty or art is that the object shall appeal to the eye, which is usually accomplished by symmetry of design or repetition of distances. You do not have to use automobiles to demonstrate that; you can apply it to anything. Assume two buildings, both well-built, substantial structures, placed side by side; one will appeal to the eye and the other will not on account of the architectural design. That is what Mr. Stout means by beauty of design. To get beauty we must have repetition of distance, symmetry of design and, as he says, curved surfaces that we can look at from the forward end of the airplane, following back without looking here and there at angles that break the curve.

MR. WILKIN:—In 1950 the airplanes may not even have a tail.

MR. COOK:—They may have flying wings, as Mr. Stout has advocated for years and on which more or less work is being done in Germany today. Junkers is supposedly building a ship that is practically nothing but flying wings, with very little fuselage, the staterooms as well as the engine room being in the wings.

The problem of noise will be very difficult to solve. We shall solve it by proper insulation of some kind. The Fokker airplanes today are not nearly as noisy as the Ford three-engine airplanes for the simple reason that the Fokker company uses soft fabrics on the inside of the cabin, which deadens the sound. The Ford airplanes are of all-metal construction and are very good conductors of noise.

The new Wasp engine does not seem to me as noisy as some of the other engines. One way in which noise can be minimized is to place the engine in a position where the noise does not reach the passengers, above them for example. Going through the air, the sound of the propellers is carried away, and that might be done with the engine. We are working on this problem and hope to solve it before long.

CHAIRMAN BARNARD:—Does any direct relation exist between the size of the airplane and the possibility of keeping the noise away from the passenger compartment? Certainly the larger craft are quieter than the smaller ones, as the engines are farther from the passenger cabin, but do the larger craft possess an inherent tendency, because of greater distance separating the various units, to be quieter than the small ones, and is that a determining factor in the style and size of airplanes that are now undergoing development?

MR. COOK:—One way of mitigating noise is to place the engine, if possible, where the noise will go in a direction away from the cabin. The most logical place

[6] A.S.A.E.—Service manager, Central Air Terminal Co., Chicago.

[7] Airways engineer, bureau of lighthouses, Department of Commerce, City of Washington.

[8] M.S.A.E.—Automotive engineer, lubricating department, Standard Oil Co. of Indiana, Chicago.

for it is above the wings. Putting the engine up in the air, so that the air current will carry the sound away from the passengers, is to be considered, and in addition we must develop something to deaden sound. Our visualization of the large airplane is one in which the windows would be two thicknesses of glass, tightly fitted so that they could not be opened, but with a regulated system of ventilation. These are problems that we have to meet and that are being studied all the time. They are visions that we have of the larger and future transport airplanes.

T. L. ROBINSON[9]:—The aircraft-engine manufacturers are fortunate in that the engine-noises are masked by the propeller noises and the noise from the exhaust. The rattle and clatter resulting largely from the increased clearances necessary is prohibitive, as judged by automobile-engine standards. I know of one powerplant engineer who was rather afraid to stay in the test room with his engine after he heard it run for the first time with a muffler on. It sounded as if it were going to pieces almost any minute, although it was actually a very successful engine.

CHAIRMAN BARNARD:—That is true. I had an experience driving back from the East early in the summer. One of the National Air Transport's Boeing airplanes alarmed me greatly. I was driving along a narrow road and heard a tremendous clanking, rumbling and chugging that sounded like a fire truck on the road right behind me. My hair went right up on end. I wondered if I had overlooked a railroad crossing that was in the neighborhood. I looked out of the window and saw this Boeing, hedge-hopping alongside of me with the engine throttled down so that none of the characteristic roar and propeller hum was evident.

MR. COOK:—I have a faint recollection of some automotive engineer telling me his experience in his first airplane ride. He thought the engine was going to fall to pieces, it was so noisy.

Larger or Smaller Airplanes?

CHAIRMAN BARNARD:—I should like to hear Mr. Cook's comments on whether he believes that the tendency in the immediate future will be toward bigger airplanes than we have now or toward even slightly smaller ones. When airplanes are made huge affairs carrying a dozen passengers or even more, they become more unwieldy and must operate on more closely defined schedules and over more closely defined routes. The possibility that appeals to me in air travel is not to have one tremendous ship a day going from Chicago to Salt Lake City or New York City, but rather to find three or four or a half dozen fast and perhaps smaller airplanes leaving at intervals of a few hours. The same thing attracts most people of the United States to the automobile from a utility standpoint; that is, its convenience and flexibility as a conveyance to take them where they want to go whenever they feel like going. I am not able to visualize the effectiveness of these great passenger airplanes, even some that are being built and put into operation in this Country at present, let alone some of those we hear about every now and then, for instance the new big German ship of 100-passenger capacity.

[9] M.S.A.E.—Chief engineer, McGill Metal Co., Valparaiso, Ind.

[10] M.S.A.E.—In charge of air-transportation department, Pyle National Co., Chicago.

MR. COOK:—What the transport airplane will be in the future we do not know. Aviation is moving so fast that what I say tonight might be obsolete tomorrow. We vision today an airplane that is large enough to give 30 passengers or less the comforts of a Pullman car, with a place where they can move about, a lounging room where they can gather, and compartments or berths to which they may go if they feel so inclined. Whether the last will be a fixed berth, as we have in a steamship today, or convertible berths like those of the railroad sleeping car, is hard to tell but some place must be provided where the passengers can lie down for a little rest or, if they desire, gather around the bridge table for a game of cards.

As Mr. Barnard says, we also foresee airplanes leaving from a given point for a given destination every hour or two, instead of twice a day, so that we can do about the same as we do with the motorcoach lines today. The idea of one of the most successful airplane transportation operators in the Country, with whom I talked recently regarding the future of air transportation, is not to dispatch a scheduled airplane in the morning or in the afternoon, but perhaps smaller airplanes such as I have indicated leaving on a 1 or 2-hr. schedule for a given point.

Night flying is bound to come, and before long we shall be able to leave Chicago at 5 or 6 o'clock in the evening and arrive at New York City in time for breakfast.

Night Flying Awaits Better Lighting

E. A. SIPP[10]:—Several years ago, when we started our first constructive experiments in night flying, we were told by our officer in charge that we were a little inclined toward our local insane asylum. Later, however, when the Post Office Department entered the airmail business and decided that night was really the time to fly the mail, assistance was requested of the Air Corps. We all realize that if a man is in a hurry to get somewhere and wants to save a business day, the night is the time to make the trip. In the development of our National night airways the Airways Division of the Department of Commerce in particular has done an important job. Not only are the lighted airways a potential route for military movements, but they are also a wonderful route for commercial passenger night-transport operation. Beacons are now located 10 miles apart and, when the volume of traffic warrants, they may be only 3 miles apart. Night flying is not yet safe, from most laymen's point of view, although it is from the point of view of the commercial mail or express operator. To make it safe enough to warrant passenger carrying, we must have beacons located closer together and do many more things with lighting than has been accomplished to date. What is the Stout organization doing with respect to night flying or experiments with lighting?

MR. COOK:—We have done nothing so far as lighting is concerned. The University of Detroit made an innovation this year by playing football at night. I went over to the game one night and could not help thinking of what was being done in the way of illumination. That field was as bright as any sunshiny day, and I could see all the details of the play. The field was free from shadows and we had no glare in our eyes. The seats opposite to us were so dark that we could see people lighting cigarettes. It made me think of the possibili-

ties of lighting airplane fields. Of course, we could not have numerous high poles erected around the landing-field, but better illumination is coming.

The Grosse Ile airport in Detroit has recently installed a new system of field-lighting in which the wind vane illuminates the runway on which a pilot is to land. The lights are sunk in the ground in such a way that they cannot be damaged if an airplane runs over them and are so controlled that if a pilot comes over the field at night, a man in a tower or a watchman on the field can give code signals by blinking the lights.

Within the next year or so, night flying will be as safe as day flying, and I think it will be safer except in bad weather, which we all have to fight, because the air is more stable at night than it is in the daytime. That was brought very forcefully to my attention by Mr. Hill, of balloon fame, who won the 1928 Gordon-Bennett race. The last night that he was in the air, before landing at Macon, Ga., he just drifted along about 200 ft. above the ground. When the balloon came to a hill it would ascend slightly and after it passed over the top would descend, following the contour of the earth, the air was so stable and smooth. On the day that he left the Ford airport, he had been presented with a kind of vegetable candy for food. On that last night he could throw out a bar of this about as big as a Hershey chocolate bar and could feel the balloon rise slightly. Balloonists always like night flying better than day flying for that reason; therefore I believe that night flying will sometime be much safer than day flying on account of the stability of the air.

The General Electric Co. has been performing some wonderful experiments with the Neon and the Cooper Hewitt lights. I understand that some combination of them is installed in basements in New York City and that stepping into one of these basements is just like going into a sunlighted room.

The Problem of Blind Flying

MR. LEBAIE:—Fog is a problem that will have to be solved before commercial passenger-flying at night will be possible. The Bureau of Standards has a visual indicator operated by a radio beacon, which should be of great assistance in fog-flying. Fogs, so far as we know, cannot be penetrated by any light that is available at present. The indicator has two reeds that vibrate at the same frequency when a pilot is directly on his course; if he gets off the course in one direction the opposite reed vibrates faster. Lieut. James Doolittle recently flew for 15 miles completely enclosed in the cockpit; he took off and made a landing, flying entirely by instruments.

CHAIRMAN BARNARD:—Lieutenant Doolittle's recent experiment has attracted more attention than anything that has happened in a long while in the field of aviation. It has conveyed the impression that probably the greatest hazard is about to be overcome. Being able to take an airplane up, fly it and bring it down again all in one piece without seeing where you are going has started some imaginations working.

MR. CORNELL:—Has that radio-signal method been used to indicate altitude too?

MR. LEBAIE:—We are trying to thresh out that problem, using what I think is called a static altimeter, but have not progressed very far. No really good altimeter is now available. I do not know what Lieutenant Doolittle has back in the East, but he has many devices that very few persons know anything about.

The Packard Diesel Aircraft-Engine

(*Concluded from p. 442*)

hr. on the dynamometer with one of the later experimental models, with an output equivalent to ten of the standard Army, Navy and Department of Commerce Government acceptance tests. This program has covered a period of two and one-half years of intensive test work, much of it done on a day-and-night basis.

Simplification and further economies in the operation of transport planes can be definitely prophesied as a result of this development of the Diesel aircraft-engine. Large transport, mail and freight planes will be driven either by a single Diesel engine of large power or possibly by two smaller engines mounted on the wings so as to remove the sources of noise from the passenger compartment. Thus a high degree of safety and low cost of operation will be arrived at, thereby greatly stimulating the growth of commercial aviation.

Standardization from the Cruiser Builder's Viewpoint

By H. R. SUTPHEN[1] MOTORBOAT MEETING PAPER

TWENTY or even 10 years ago, the success of the standardized cruiser might have been questioned but today even the most conservative yachtsman has become converted. What has caused this change in attitude? Why are many builders offering standardized cruisers today when five years ago only so few were? To my mind this is because standardization has enabled the boat-builder to perfect the design and production of small cruisers and the boat buyer has recognized the dollar value that they offer.

I have been an enthusiast on the subject of standardized boats for many years and have always felt that the advantages resulting from the proper development of this principle should be obvious to anyone. Many obstacles had to be overcome before we reached our present happy state. One of these was the prejudice of the yachtsman against the so-called stock boat, the general idea being that it was built solely with the idea of cheapness, using inferior materials, and was assembled by "wood butchers" instead of by boat-builders. Unfortunately, some of the early boats deserved their reputation. They were unsightly and unsafe, and a season of salt-water use made defects apparent and the owner disgusted. That was one prejudice which has been overcome by years of education and demonstration.

One enthusiastic owner of our boats was so annoyed by the mistaken ideas of his fellow yacht-club members that he organized and financed a trip from a distant city to Bayonne, N. J., for a dozen or more "doubting Thomases" and showed them just how the modern boat is built. Many more standardized cruisers are anchored in his home port now. These men were old-timers and each thought that to get an honest boat it must be specially designed and specially built and every point of its design, construction and equipment personally supervised. When they saw how every detail, on which they would have been particular, had been taken care of and a multitude of items, of which they had never thought, were provided for, they realized that even their experience did not qualify them to criticize our boat in details of design and construction.

Another obstacle to overcome was what we called "backyard" competition. This was furnished by the local boat-builder who stored and repaired boats and built one or two boats in winter just to keep busy. His failing was to persuade a victim that he could duplicate standardized cruisers for the same cost and, as he said, "make them right." Nine times out of ten he failed in his promise of price, performance and delivery. This man, however, is learning that to act as an agent and sell a good standardized cruiser to his neighbor and keep him as a friend is much more profitable.

What Is Standardization?

The subject of standardization is dealt with in many lines of industry and in the motorboat field the term is now commonly used, but certainly in some cases is incorrectly applied and is perhaps therefore tending to lose, in these applications, what should be its correct meaning. The fact that without standardization and the resulting quantity or mass production the present high standard of living as enjoyed in our Country could never have been attained is now fully recognized. Likewise, without it, the present condition in our own industry certainly would not be anywhere nearly so far advanced. The old doctrine that mass production was necessarily destructive of high quality has long since been definitely exploded and exactly the contrary proved. Imagine what present conditions would have been without the art of standardization having been applied to, for instance, the automobile industry.

[1] M.S.A.E.—Vice-president, Electric Boat Co., New York City.

A misconceived popular idea that a standardized cruiser must necessarily be inferior to a specially built craft has been, and to some extent still is, prevalent. But we in the industry know, from our own experience and observation, that the motorboats produced today by the more prominent builders who have actually standardized their product are far superior to any that have ever been built to special order. In our own field the industry has more or less appropriately divided itself into several branches, covering the manufacture of engines, auxiliary parts, hardware and various accessories; and the boat-builders are very definitely divided into three sections, some building outboards, some runabouts and others cruisers. This probably is as it should be, because the outboard hull is a simple piece of construction as compared with the runabout, while the cruiser is a most intricate and complicated mechanism.

Standardization, literally applied, presumably should indicate that every piece entering into the finished product is made separately and, without any preliminary association with its neighboring parts, can be assembled into the whole without change and that all such parts are interchangeable with all like parts. This, of course, cannot be made literally true, even in a much less complicated structure than a cruising motorboat. On numerous parts of a boat's construction standardization would not be practical even if the quantity were very great. Therefore, we can assume that, to be properly termed standardized, a cruiser should have at least a majority of its parts so made.

Deviations from Standard Production Unsatisfactory

Obviously, to attain this end, the boat must be produced in at least a reasonable number without change or without altering any of its main features. Whether some of the so-called standardized boats, built in only small quantities or a few at a time, are really standardized in the sense that should imply advantages due to quantity production is at least questionable.

Our own experience indicates that deviations from our standardized production sometimes requested by individual customers, even in seemingly insignificant parts, will usually be expensive, troublesome and often disappointing in the end, while the substitution of some other powerplant, for instance, is usually very disastrous to standardization, as it affects so many other vital parts.

Our experience has led us to believe that, from a given over-all length, beam and displacement, a better product is secured by determining beforehand what interior cabin combinations can be afforded and a definite location for the powerplant with the definite horsepower to be applied, and building around that without allowing for larger or smaller horsepower in engine or for a change in cabin arrangement. I think this is a matter of educating the public to realize that a given over-all length of boat planned in such a way, both from the builder's point of view of construction and from the experience gained from the users of boats, would offer the greatest value for the money expended, would have a higher resale value and be a real asset to the purchaser if he wanted to dispose of or exchange it.

Motorboats produced today by the more prominent builders who have standardized their product are far superior to any specially built vessels.

Building a motorboat involves all of the trades required in building construction and some that are concerned in building automobiles, and the providing of material for all these trades is a problem of great moment.

Motorboat building is a task for specialists, but many of the now seemingly insurmountable problems will be easily solved when demand is sufficiently increased.

Plants should be located where demand exists and waterways are available, but with standardization motorboats can be built on the Atlantic Coast and assembled on the Pacific Coast.

Standardization has been the largest factor in the industry's present healthy condition and is a success.

Difficulties of Cruiser Standardization

The cruiser undoubtedly presents a very difficult problem for thorough standardization. This is because not only of its complicated nature but also sometimes of its size and the bulk of some of its parts. A considerable number of trades are necessarily involved, and, of course, the different trades consume different classes of material. Besides the woodworkers, who are themselves divided into several classes, including boatbuilders, millwrights, plankers, fasteners, calkers, joiners, cabinet makers and installation joiners, the construction requires the imployment of machinists, foundrymen, engine men, electricians, plumbers, tinsmiths, riggers, painters, upholsterers and laborers.

This list of trades involved includes every line engaged in constructing a building or a house and in addition the trades that are involved in building the automobile of today, as what we are talking of is not only a vehicle of transportation but a home afloat as well. The so-called model house has been a long time in evolving and is probably nearer to becoming a success today than ever before, because of the high cost of labor and materials since the war. Our problem is to build a model house in a cruiser, if we can do so, that will suit the greatest number of people.

One of the most difficult features lies in providing the material for all these trades so that it will be available when needed and yet not ordered too far in advance, thus prolonging the interval of inventory turnover, increasing the inventory investment and requiring more storeroom space. Furnishing materials for a single model or two, having a nearly uniform rate of production, would be comparatively easy, but, as in our own case, for instance, where six different models are produced, combined with a more or less seasonable delivery schedule, the material problem becomes of great moment.

Another of the problems is the determination of costs, both as to the different models and as to various trades or divisions for each model. This information most

certainly is necessary so as to maintain efficiency and a continuing business, for no business organization or industry can long continue without making a profit. We have found after a long while that a properly organized perpetual inventory is of the greatest help both in material control and in the determination of costs.

Size of the product constitutes another problem. A cruising boat is a very unwieldy article when out of its natural habitat, being comparatively difficult to move about and to store. The storage space required for the finished boats of a year's production from our own works would equal about 180,000 sq. ft., or more than 4 acres, and this must, for practical purposes, all be ground or first-floor area.

The number of parts entering into the finished cruiser is really multitudinous, and the number of operations is legion. For workmen to become proficient in the performance of these operations takes time; in fact, we have found that their efficiency is increasing even after the production of literally hundreds of cruisers of identically the same model.

A Task for the Specialist

If you look through some of the boats you will be amazed to see how every inch of space is occupied and how we get the so-called lockers and drawers into their places. You would not think that a man could work in the confined spaces in which these compartments are located. From experience we know that we cannot provide too much locker space, because something always is to be put in. If space is not available the article is thrown around, which makes an untidy boat, and may be destroyed or lost. The differences in cost between putting in these little refinements and omitting them is great indeed. Those of the public who know have learned that such conveniences are essential and demand them.

For these reasons, as well as for the difficulties encountered in transportation for distant delivery and for other purely manufacturing causes, the cruiser builder has perhaps a more difficult, although perhaps a more interesting, job than has the builder of smaller boats or of many other products. It is most certainly a task for specialists, but many of the problems now seemingly insurmountable will be easily solved when demand, and therefore production, is sufficiently increased.

We look forward to the time when the production of each plant will perhaps be confined to only one standardized model, or, further, to the time when one main fabricating plant will supply all the finished parts to several erecting plants located at such strategic points as the demands might indicate. Our own experience during the war, when we built the 700 famous 80-ft. M.L's, fabricating all the materials at our main plant at Bayonne, N. J., and assembling the boats at Montreal and Quebec, in Canada, is ample proof of the practicability of this procedure.

The question of location for building standardized boats is important. Plants naturally would be located in territories where the boats are in demand and waterways are available for their use. Cruising boats, in the majority of cases, cannot be shipped by rail. They are too big; therefore they have to be delivered to the ultimate customer under their own power. We should like very much to do business on the Pacific Coast, and have made sales there, but delivery from the Atlantic Coast constitutes a problem. If shipped on steamers, which is a common thing to do today, and the steamship companies are willing to handle boats of all sizes, the risk of the boat being damaged is very great. Particularly in the trip through the Panama Canal, the atmospheric changes that occur are rather hard on a new boat, especially if heavy weather is experienced. So we feel that ultimately we should like to have an assembling plant on the Pacific Coast, which would be logical if the demand warranted it. When that condition arises I think we shall be prepared to meet it.

From our experience we know that this is the practical thing to do. When we offered in 1915 to build 50 submarine chasers for Great Britain in 18 months, the people in England did not think we could fulfill the contract in the time we guaranteed, but they gave us the order because it was a war measure. We had no sooner finished our first boat than we had the order increased to 550, and we finished those 550 in a shorter time than we thought we could the first 50. This was all accomplished through standardization. Having the assembling plants away from the fabricating plants was most helpful in this case, as those in charge of assembling had nothing to do with the material and fabricating problems, and those in charge of fabricating had no worries about erecting and assembling.

This matter of fabricating parts of a boat at one point and assembling them at another is no mystery if the demand and quantity are sufficient. In a much larger way this was further proved during the war by our organization when we built 150 steel cargo-ships of 5000-tons displacement. Those vessels were assembled in Newark, N. J., and, because of the standardized design, the parts, which were fabricated as far west as St. Paul and Kansas City, came in and fitted perfectly. At the high point of production we were building a complete ship, worth $1,000,000, every three working days.

Requirements for Successful Standardized Cruisers

The basic requirement is, of course, a correct design for production. Sales methods may be perfect but if the underlying design is not right no amount of effort can make it a continued success. Size and accommodations must necessarily be determined by individual and family requirements, and arrangement is to some extent a matter of personal opinion or fancy. However, certain fundamental requirements must be incorporated to a greater or less extent in every successful design or model. These include seaworthiness and safety, comfort and convenience, speed and efficiency of operation, economy of maintenance, appearance and correct proportion and rugged but yet economical construction.

No mathematical rule or known formula exists whereby the correct relative importance of these factors can be evaluated. Here the builder's judgment comes into play, and in the end this judgment will determine the measure of success or failure of the product. Unfortunately, or perhaps fortunately, competency to render this judgment can be obtained only by proper and continued experience, and this experience cannot be derived from any other line of endeavor but can be had only by long and close association with, and observance of, a great many boats under all conditions of service. To this basic experience of the designer should be added the experience, observations and ideas of the owners, this owner experience in the aggregate being necessarily a considerable part of the knowledge built into success-

ful designs. On the other hand, the builder must be on his guard and not be stampeded into perhaps freak ideas of individual owners.

In addition to the well-known advantages of reduced manufacturing costs and increased output, many subsidiary advantages combine to give an improved product and therefore increased value. In design, all parts and accessories can be worked out to best advantage, and special parts can be made to suit their respective purposes and applications, so that they are far more appropriate than any commercial parts obtainable. Much greater attention can be paid to all details than is possible without quantity production, and innumerable small but important details can be controlled from the standpoint of design, which would be impractical or impossible to touch upon, or even think of, without large production. Selection of materials can be made with greater care, so that their suitability for the various purposes is enhanced, assuring both durability and safety. Inspection can control the uniformity of the parts and materials as specified, assuring against defective parts and promoting interchangeability, which is so important from a servicing standpoint.

Proper design, construction and inspection naturally will be a guarantee of the greatest possible degree of carefree service in the hands of the owner, relieving him of the annoyance, inconvenience, expense or even danger arising from inferior design or construction. It will also assure him of relief from inconvenience and unnecessary expense in replacement of such parts as are inevitably subject to wear, provided the builder maintains a properly stocked and properly organized service and parts department. The item of service is of paramount importance from the owner's standpoint, and when he buys a really standardized cruiser from an established builder this should be one of the major advantages purchased with the boat, and only because of thorough standardization can this service be obtained.

In addition, we have found that, on standardized models, the owner can be greatly assisted by uniform standardized seasonal overhauling programs, and he appreciates this assistance. Under this system, the owner has the advantage of being relieved of all worry incidental to the determination of what overhauling should be done, leaving this with the builder or his authorized agent with whom the boat is stored; and also he has the advantage of knowing beforehand just what the work will cost.

Another, and one of the most important, advantages of standardization is the opportunity offered for experimentation and development of new ideas, new materials and new processes, because with quantity production the builder can afford development expense that can be spread over the entire series, becoming a very small item in the cost of each boat.

In conclusion, after considering our own experience of almost 40 years in standardizing motorboats, and especially the last 10 years or so when production has really reached the quantity basis and has been on the increase, we feel that standardization has been the largest factor in placing the industry in its present healthy condition. However, very much is yet to be done along this line, as demand and production increase. We still have work to do in this direction, but we are for it. We want to encourage it, not only because we know that this is the only hope of ever building up the industry, but also because we know that the public will get more pleasure, enjoyment and real value for the money expended by it in an industry founded on such procedure than in any other way we know of. To put it briefly, we might sum up by the phrase, "Standardization is a success."

THE DISCUSSION

GERALD T. WHITE[2]:—If I remember correctly, the proportion of us who are making more, we will say, than $7,000 a year income is very small. I wonder if, in Mr. Sutphen's opinion, a $5,000-a-year man may ever hope to have a cruiser, or if that is entirely out of the question?

H. R. SUTPHEN:—Without question the $5,000-a-year man will own a motorboat, but we must give him one that is an asset and not a liability. If we can get the idea over that people can realize on a good motorboat, they will not be so fearful of investing in one as they are now. In the old days they thought that their money was thrown out of the window when they bought a motorboat. If we get the public to appreciate that a motorboat has good resale value, and give them convenient and economical mooring facilities and a location in which to tie up the boat without having it pilfered, destroyed or otherwise damaged, then we shall see motorboats in general use. In my opinion, the deterring factor today is not the expense but lack of education.

IRWIN CHASE[3]:—I think our market lies with the $5,000-a-year man. I do not see any reason why we shall not sell to him. As a matter of fact, we are selling many cruisers to people who are not making $5,000 a year. One might as well say that a man cannot afford to live in a house if he does not make $5,000 a year, because that is what a cruiser is. I have in mind several of our owners who use their cruisers as a house.

The main expense is depreciation, and that is taken care of by the varying price of the dollar. I know many cases in which the motorboat is worth more than it cost, but under normal conditions, if the owners have a good standardized vessel they will have the minimum depreciation. Another expense is insurance, and we have done much to make motorboats safe so that the insurance companies would keep the cost of insurance down. I believe, as a matter of fact, that, by talking with insurance companies and showing them that our vessels are good standardized craft and better than the average, we have been able to get rates that are a big help to the owner. In the matter of upkeep, people with small incomes do much of that themselves, as Mr. White knows. Then the cost of storage has to be considered. But, with a standardized motorboat, the expense for storage and repairs can be brought down to a low level.

I think the real hope for the $5,000 man is a standardized motorboat. We have dozens of owners that do not make $5,000 a year who are having a good time with their cruisers.

[2] M.S.A.E.—Editor, *Motorboat*, New York City.
[3] Manager, Elco Works of the Electric Boat Co., Bayonne, N. J.

Mixture Distribution

By Alex Taub[1]

Annual Meeting Paper *Illustrated with* Charts and Drawings

HOPING that discussion and dissemination of information on the fundamentals of distribution routine will continue, the author reiterates known facts, which include (*a*) the method of charting distribution progress, (*b*) a suggestion for locating the error in distribution and (*c*) a series of thoughts on construction. The paper is divided into two parts, the first being a study of distribution routine and the other a discussion of a few of the problems that are met every day in the search for perfect distribution.

Complete satisfactory distribution and the quantitative measurement of its quality are the two major problems of distribution. The interrelation of these problems is mentioned and the complexity of the subject of distribution is emphasized by listing nine detailed factors, the point being made that if the information that engineers have on these items could be collected and codified considerable progress would be made. Following this, the usual test procedure of runs for power, economy and friction is outlined, and the questions of efficiency based on air consumption, economy versus power, the maximum-economy point and car-driving loads are discussed, and the procedure to be followed in securing this information described.

The employment of preheated air or an externally heated T-manifold to heat the mixture is discussed and the conclusion is drawn that distribution of extremely lean mixtures is improved by the use of heated air. The author emphasizes the importance of using data to indicate where errors in distribution occur and comparing mixture fishhooks for a quantitative measurement.

In Part 2 consideration is given to the influence of the carbureter on distribution, throttle-plate deflection, balancing the airstream and the relation of manifold and valve size. The recommendation is made that the valve capacity that would give a high-speed range exceeding the requirements should be used and the top range limited to the required point by decreasing the area of the manifold. Precipitation and its control by the application of heat, the means employed to divide the wet fuel accurately and keeping the fuel in the airstream by correct design are mentioned and concrete examples given.

The discussion, which was almost exclusively written contributions, emphasized the analytical value of the fishhooks, established a criterion for part-load efficiency, mentioned the use of separators to indicate the faults of the distribution by catching the unvaporized fuel, pointed out the effect of the direction in which the carbureter air-horn was turned on the richness of the air-fuel mixture, described the task of the carbureter engineer in adapting his design to an engine, presented data on air and fuel distribution and the application of heat and mentioned the possibility of using indicator diagrams to measure the relative filling of the several cylinders.

PART 1—A STUDY OF DISTRIBUTION ROUTINE

I AM AWARE that considerable has been written on the subject of distribution as manifested in the operation of automotive powerplants. In the past, the subject has been presented by engineers representing car manufacturers, carbureter manufacturers and various sales organizations. Today, the subject appears to be entirely in the hands of the physicists, who, without doubt, have made notable progress. This progress, however, has been more or less one-sided. The problems of distribution are complex. They involve two major problems: (*a*) how to obtain satisfactory distribution and (*b*) measurement of its quality quantitatively.

The Physicist and the Engineer

The physicist's efforts have been almost without exception on the side of (*b*). We have therefore heard considerable concerning exhaust-gas analysis and the spectroscope. The former, which has been or is being used, has definite limitations, particularly where ports are siamesed or the development work is under pressure. The spectroscope is still a spectroscope, the plaything of the physicist, and its most ardent proponent would hesitate to include it with regular equipment. Obviously, applying either of these methods to routine development work is difficult.

A need exists for a routine method, which might be forthcoming if this topic could be openly discussed and the routine of various engineers pooled or consolidated. Thus the most vital engineering problem would be back into the hands of the engineer, where it undoubtedly belongs.

A definite reluctance is manifest on the part of the engineer to come out into the open on matters pertaining to distribution. The goal of this paper is to promote discussion of such matters. Therefore, this portion deals with routine and incorporates repetition of many things, particularly controversial points.

The two major problems previously mentioned are interrelated. We can hardly expect to progress in the quality of the mixture distribution until we are able to apply, in some degree, a form of measurement. The complexity of the problem of measurement is understood by all and is borne out by the earnest introduction of the spectroscope as an aid to a solution. The complexity of the problem of distribution as it exists is brought home when we list the detailed problems involved. Under quality we must deal with (*a*) degree of atomization, (*b*) lack of homogeneity of the mixture, (*c*) precipitation, (*d*) division of wet ends, (*e*) division of air-flow, (*f*) application of heat, (*g*) manifold design, (*h*) port design and (*i*) port inserts. Each of these items is a separate problem, and no doubt con-

[1] M.S.A.E.—Research engineer, Chevrolet Motor Co., Detroit.

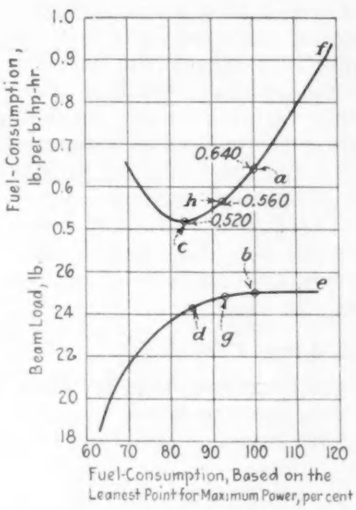


Fig. 1—A Typical Mixture Fishhook Curve

This Curve, Which Was Taken at a Speed of 1000 R.P.M., Is a Combination of the Curves of Specific Fuel-Consumption and Beam Load Plotted against Percentages of the Fuel Consumption at the Leanest Point for Maximum Power

siderable information on each one exists in the minds of engineers, which, if collected and codified, would represent much progress.

Measurement

Let us assume that we have before us a complete powerplant and are to determine the characteristics of this unit. Following the usual procedure, we would place this engine on the stand and stabilize the friction. Runs would be made for power, economy and friction. This information would be converted to brake mean effective pressure, torque, horsepower, mechanical efficiency and thermal efficiency. The method of obtaining these data will depend upon the reason behind the investigation.

If the carbureter is set for maximum power at one speed, and all runs at other speeds are made with this setting, the information forthcoming can represent only the carbureter characteristics. The engine potential is beclouded by the characteristics of the particular carbureter used.

Efficiency Based on Air Consumption

If the information desired is to include the engine characteristics, the carbureter must be adjusted for every speed at which readings are to be taken. Under this procedure, carbureter characteristics are eliminated and engine potential is obtained, including whatever deficiencies may exist in distribution, restriction and the like.

To carry the investigation of engine potential one step further and eliminate distribution, thermal-efficiency curves must be plotted on the basis of air consumption rather than fuel consumption. The air consumption will be a constant, unaffected by the vagaries of the manifold or ports, except in the matter of total volume. Ricardo has made some very definite recommendations in his writings for the use of comparisons by air consumption rather than by fuel consumption.

Getting back to adjusting the carbureter for every speed, let us assume a methodical procedure for such adjustments; otherwise we are obliged to accept the judgment of the dynamometer operator as to the point of best setting for each speed. Let us lean the carbureter down to the point where the engine runs irregularly and then enrich the mixture slightly to obtain a condition that is barely steady enough to permit a reading of fuel and load. We shall then be at the leanest point of operation at which a reading can be taken. Progressive readings should be taken by steps to approximately two points past the maximum-power point. With this information we can plot a combination curve, as shown in Fig. 1, that incorporates graphs of specific fuel-consumption and beam load against pounds of fuel per hour.

Three points on these curves are worthy of consideration. They are *a*, the ideal-economy point, which is the one selected by the engineer as representing a desirable operating-economy; *b*, the ideal-power point, which is the complementary point for power that should be available with the selected economy; and *c*, the maximum-economy point. Theoretically, point *b* should be the leanest for maximum power. However, if we study the characteristics of the power fishhook in the accompanying charts, we note that a very gradual change occurs between *d* and *e*. By studying the economy fishhook, we find that a rapid change occurs between *c* and *f*. As these portions represent complementary val-

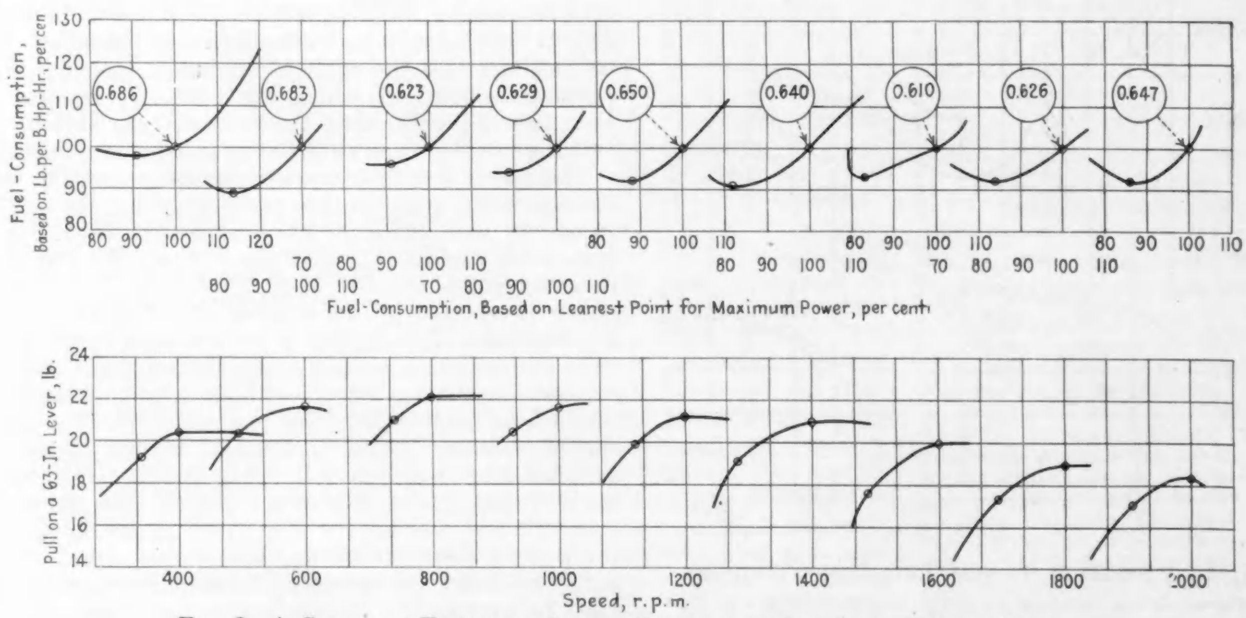


Fig. 2—A Series of Fishhook Curves Taken throughout the Speed Range

Showing How the Fuel Efficiency and the Distribution Vary with the Speed. The Figures on the Curves in the Upper Set Indicate the Specific Fuel-Consumption for the Leanest Mixture That Will Give Maximum Power

ues, we gain some idea of how much we must pay for the last ounce of ideal power.

Economy versus Power

Selecting points *a* and *b* becomes a matter of sacrificing the smallest percentage of power for a major gain in economy. Thus, on Fig. 1, if for power we should select point *c* instead of *b*, we would sacrifice 0.8 per cent of the power available. However, the complementary economy would be 0.56, or 12 per cent better than at point *a*.

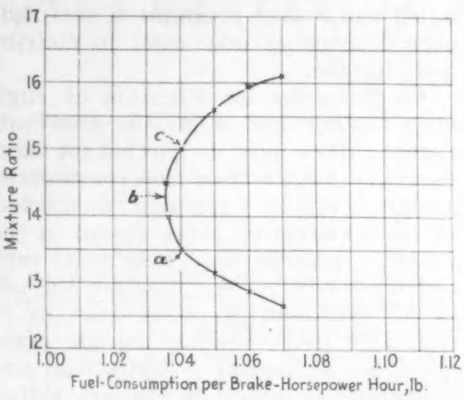


FIG. 3—CAR-DRIVING LOAD-MIXTURE FISHHOOK

Obtained at 1000 R.P.M. and a Constant Load on the Beam. The Interesting Point about It Is That, While the Fuel Economy Is Similar for Points *a* and *c*, the Operation for the Latter Setting of the Carbureter Is Ragged and Sensitive

Attention is called to the fact that the mixture curve of Fig. 1 is plotted with the pounds of fuel per hour expressed in percentage rather than in absolute values. The leanest point for maximum power which is readily selected from the dynamometer log-sheets is assumed to be 100 per cent. The reason is that this arrangement makes possible a comparison of the conditions over the speed range or under conditions where the absolute fuel-flow between comparative conditions differs widely. Obviously, considerable variance might occur in the location of these points on the curves, as compared to where they would fall if located from data taken with the standard setting of the carbureter. Perhaps, owing to conditions existing in the engine, the carbureter range cannot be modified to hit the ideal, but at least the engineer can know by this method how closely his standard carbureter follows the ideal.

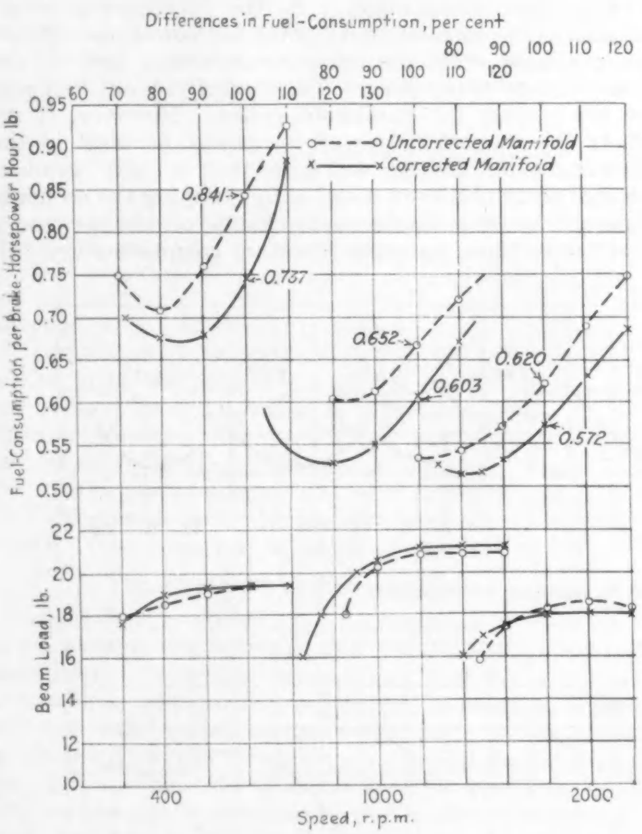


FIG. 4—A SERIES OF TYPICAL FULL-LOAD FISHHOOKS

The Curves Were Obtained at Three Engine-Speeds and Two Manifolds Were Tested at Each Speed. The Dotted Line Represents Results Obtained with the Original Manifold and the Full Line the Results after a Correction Was Made

Maximum-Economy Point

Point *c* is of little use in car operation. It is the turning point of economy and the mixture is too lean for satisfactory car-operation. However, it is by far the most significant point. It is a very stable value, maintaining its position through major engine-changes. For instance, we have found the maximum economy unaffected by six widely different types of cylinder-head. In spite of this remarkable stability, this point, in fact, the entire structure of the curve, is extremely sensitive to changes in distribution. Our recommendation lies in this fact. The truth of this is supported when we consider that the point of maximum economy represents that point at which the brake horsepower per hour lost is greater than the fuel per hour saved. Distribution is the most vital factor in effecting this ratio.

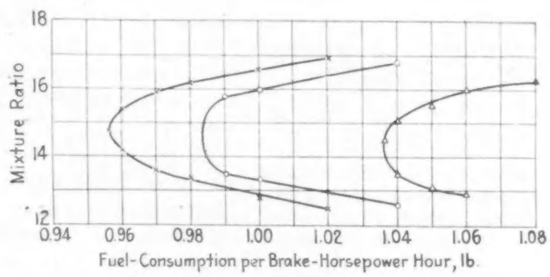


FIG. 5—TYPICAL CAR-DRIVING LOAD-MIXTURE FISHHOOKS

Obtained from a Manifold as Originally Designed and After Two Attempts at Improvement Were Made. The Total Improvement Represents a Decrease in the Specific Fuel-Consumption of from 1.036 to 0.956 Lb. per B.Hp-Hr.

The power loss is created by leanness, and the maximum-economy point is that point at which the mixture in one or more cylinders has become sufficiently lean to lose power rapidly. The distance between the maximum-economy point and the leanest mixture for maximum power is affected by the number of cylinders involved. For instance, if one cylinder is lean and all others rich, then the distance between maximum economy and leanest for maximum power will be great, because the power loss must come from one cylinder. The usable specific economy would be poorest, because all but one cylinder must waste fuel to bring the lean cylinder up to strength. The distance between the maximum economy and leanest for maximum power is shortest for perfect distribution, as all cylinders lose together, and, obviously, the economy is good because no fuel must be wasted.

These curves, which are called fishhooks in our organization because of their general shape, can become

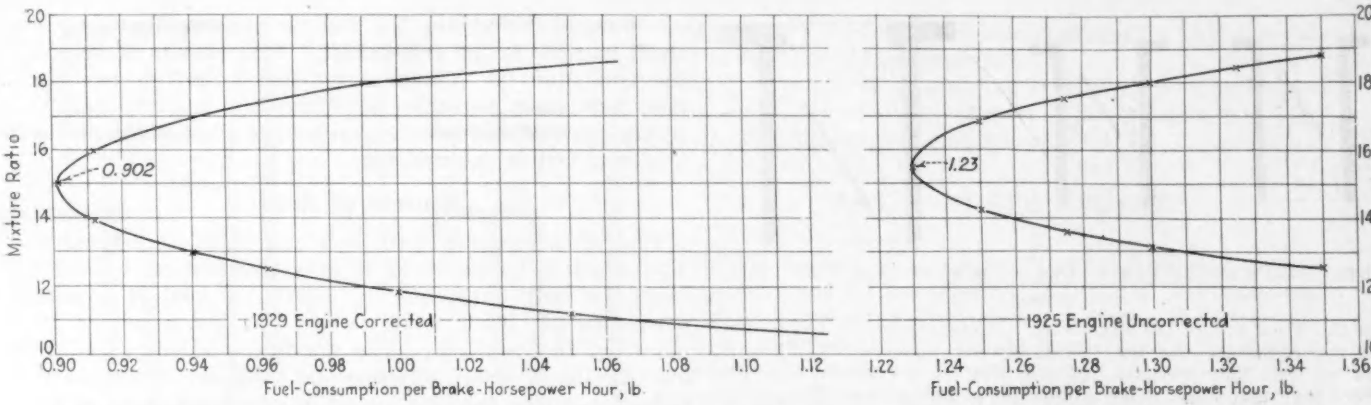


FIG. 6—CAR-DRIVING LOAD-MIXTURE FISHHOOKS SHOWING THE IMPROVEMENT MADE IN DISTRIBUTION IN FOUR YEARS

These Curves Were Taken at 1000 R.P.M. and Show That the Specific Fuel-Consumption Decreased from 1.23 Lb. per B.Hp-Hr., with a Typical 1925 Manifold as Originally Designed, to 0.902 Lb. for a Refined 1929 Manifold

very vital factors for determining the distribution quantitatively; yet the obtaining of these data demands no special knowledge or any instruments except experience and the ordinary equipment found in all our laboratories. The required readings are of a routine nature and easily obtained. Fig. 2 is a series of these curves taken through the speed range and gives some idea as to how the fuel efficiency varies with speed, and, incidentally, how the distribution varies with speed.

Car-Driving Loads

The most important virtue, among many to be obtained by good distribution, is economy. Fuel consumption on the road is not necessarily reflected in full-load fuel-consumption on the dynamometer. It is an indication, but that is all. However, fuel consumption for car-driving loads is a direct reflection of what may be expected on the road.

The procedure for car-driving load-mixture fishhooks is somewhat different than for full load. Assuming that the car is being driven on the level, the equivalent beam-load for the car-driving load for any given speed remains a constant. The throttle position will vary with every change in mixture ratio. The graph applicable to car-driving loads is shown in Fig. 3. It is based upon mixture ratio plotted against pounds of fuel per brake-horsepower-hour or mixture ratio per specific economy. This curve, like its companion curve, indicates the critical point in economy. However, it is more sensitive to distribution than the full-load curve. The outstanding points of interest on this curve are the selected-economy point *a* and the maximum-economy point *b*.

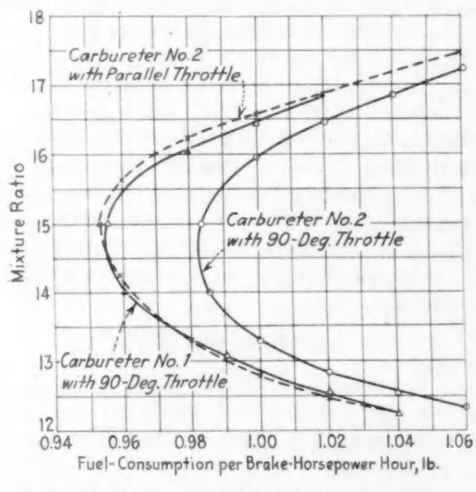


FIG. 7—CURVES SHOWING THE EFFECT OF CHANGING THE POSITION OF THE THROTTLE SHAFT WITH RELATION TO THE CRANKSHAFT

As Originally Tested, Both Carbureters Had the Throttle Shaft Located at an Angle of 90 Deg. to the Crankshaft and the Distribution with Carbureter No. 2 Was Inferior to That Obtained with the Other. Changing the Position of the Throttle Shaft of Carbureter No. 2 So That It was Parallel to the Crankshaft Made the Distribution, as Indicated by the Dotted Line, Practically the Same as That of Carbureter No. 1

Mixture Setting

Very often we have found point *a*, when checked against a standard setting, to be at *c*, and although the economy is similar for points *a* and *c*, with the setting at *c* the operation is ragged and sensitive. A report is frequently sent in that the conditions are critical because further leaning shows less economy. With the setting at *a*, we are more likely to have a strong job, without critical carburetion. If the economy is unsatisfactory, the engineer may have to correct the distribution so that the carbureter man can select a strong point with improved economy.

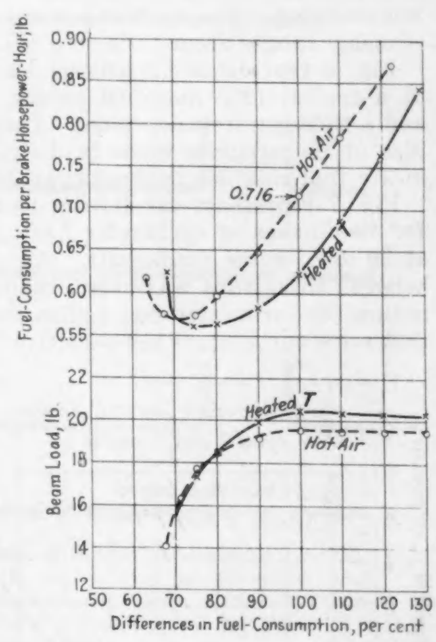


FIG. 8—TWO FULL-LOAD MIXTURE-FISHHOOKS SHOWING THE EFFECT OF VARYING THE SOURCE OF HEAT

In one Test Preheated Air Was Used as the Source of Heat and in the Other Heat Was Applied to the Manifold To Give a Mixture Temperature of 117 Deg. Fahr. While the Maximum-Economy Points Are Practically Alike, Which Would Indicate Similar Distribution for Maximum Economy Irrespective of the Source of Heat, the Wide Variation throughout the Rich Range Is Attributed to the Method of Applying Heat to the Mixture and Indicates That with Preheated Air the Distribution Breaks Down as the Air Becomes Saturated with Fuel

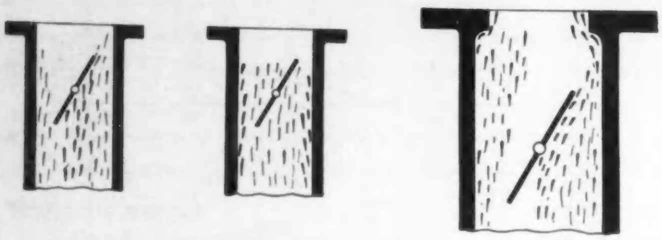


FIG. 9—THROTTLE-PLATE DEFLECTION OF AIR-FUEL MIXTURES

In the View at the Left, the Fuel Is Concentrated in the Center of the Airstream and the Heavy Mixture Is Deflected When It Strikes the Throttle-Plate. If the Fuel Is Concentrated at or Near the Outer Edge of the Airstream, as Indicated in the Central Drawing, the Mixture Tends To Clear Both Sides of the Throttle-Plate. In Some Makes of Carbureter a Hop-Off Is Included To Force the Wet Fuel from the Carbureter Riser to the Airstream, as Shown in the Drawing at the Right

I fail to see how the engineer and carbureter man can get together on any other basis.

Fig. 4 is a series of typical full-load fishhooks. Three engine-speeds and two manifold conditions are indicated. The dotted line represents a manifold that was under suspicion. The full lines represent conditions after a correction was made.

Fig. 5 is a series of typical car-driving load-mixture fishhooks and represents a manifold with two steps of improvement. The total improvement in the maximum economy ranges from 1.036 to 0.956.

Fig. 6 represents car-driving load-mixture fishhooks of a typical 1925 manifold design without correction, and a 1929 manifold corrected. These curves give some idea of the progress made in distribution and also indicate that mixture fishhooks can bring out this point.

Fig. 7 represents car-driving load-mixture fishhooks for two makes of carbureter having the throttle shaft at 90 deg. to the crankshaft. An obvious discrepancy between these runs was noted, indicating better distribution for carbureter No. 1 than for No. 2. Knowing that some carbureters are sensitive to throttle position, we changed carbureter No. 2 so as to bring the throttle shaft parallel to the crankshaft. This change corrected the condition, as indicated by the dotted curve. To note how close together the curves of the two carbureters came when the interference with the distribution was removed is interesting.

Sources of Heat

Fig. 8 represents two full-load mixture-fishhooks. The mixture temperature is held constant at 117 deg. fahr. for both runs, but the source of heat is varied, preheated air being used in one test and a heated T-manifold in the other. The maximum-economy points are practically alike, which would indicate that the distribution under the two conditions for maximum economy is alike. However, it remains to be explained why these curves vary so greatly through the rich range. I believe that this is a reflection on the method of heating the mixture and that with hot air the distribution breaks down as the air becomes saturated with fuel. Or, to reverse the order, distribution is greatly improved with hot air under extreme leanness, whereas the quality of air distribution remains relatively constant when heat is applied at the T of the manifold.

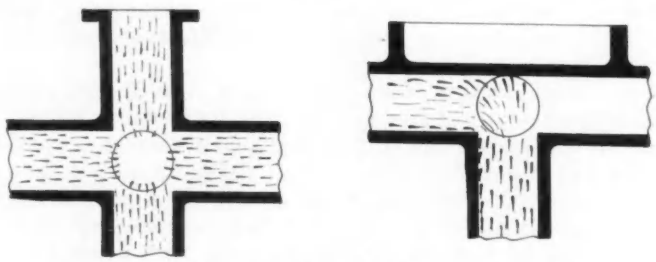


FIG. 11—FUEL-FLOW IN A FOUR-BRANCH T

I have presented graphs for indicating the over-all comparative-distribution picture, graphs sensitive to change and therefore capable of measuring distribution progress. These curves do not, however, locate the error, but merely the extent of progress between changes or between combinations.

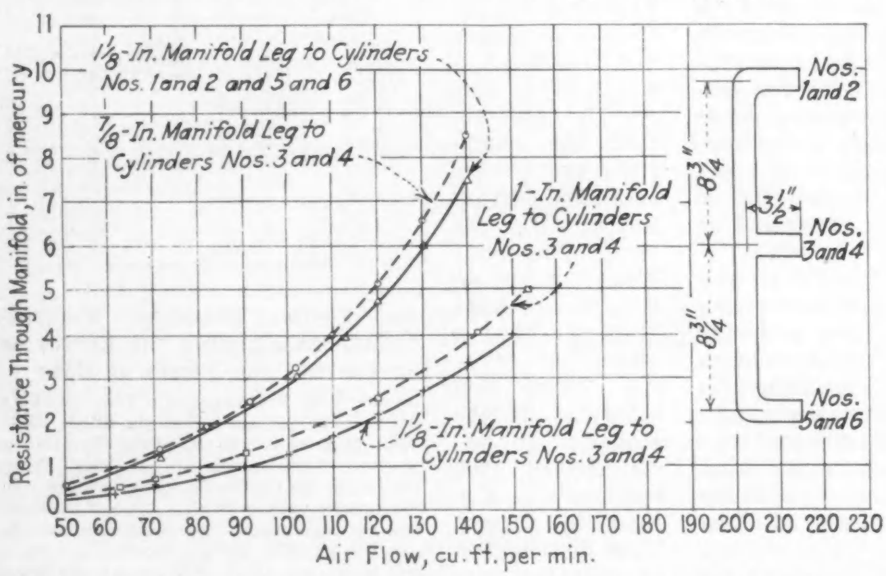


FIG. 10—CHART SHOWING THE AIR-FLOW FOR A THREE-PORT MANIFOLD

The Curves Indicate the Resistance to Air-Flow in Inches of Mercury, the Two Full-Line Curves Representing the Resistance of the Long and Short Arms Respectively as Originally Designed, While the Dotted-Line Curves Give Similar Information for Arms with Changed Dimensions

Locating the Error

Quantitative checking of distribution by locating the weak cylinder or cylinders is a method that has been used since the passing of the one-cylinder engine. Obviously, it is crude and lacks dependability, but can we not modify its crudities by limiting its use and applying method?

When locating weak cylinders, we must remember that a standard mixture-ratio usually is sufficiently rich to bring the lean cylinders up to strength. Therefore, our first consideration must be the readjustment of the carbureter for a given speed to a point where the lean cylinders are lean and consequently weak. Obviously, under these conditions, the difference between weak and strong cylinders is exaggerated, and the low spots are readily picked out.

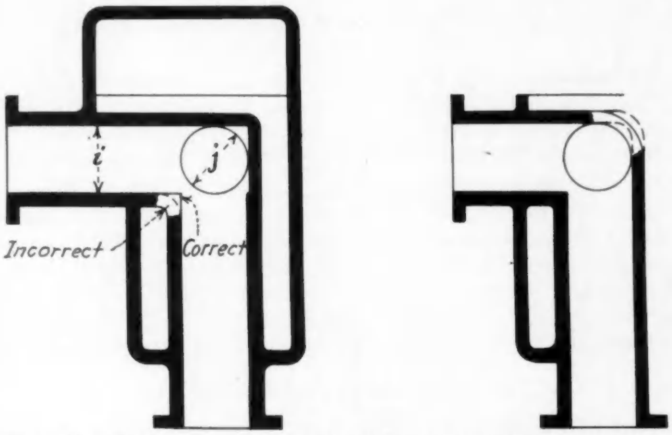


FIG. 12—SUGGESTED CORRECTIONS IN THE CENTER-PORT INTERSECTION

In the Drawing at the Right the Rebound Wall Is Shaped To Guide Wet Fuel into the Center Port

In a four-cylinder engine, we should determine the weak individual cylinders and the weak pairs. In a six, we check individual pairs and threes. For an eight, we should check individual pairs and fours. In fact, we should check every division of the inducted charge by the groups of cylinders affected. Data so obtained can be used only as an indication as to where the difficulty lies and should never be used quantitatively. The quantitative progress can be measured by the comparison of mixture fishhooks.

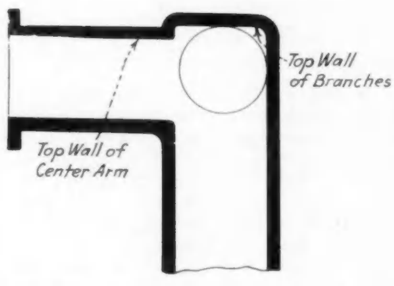


FIG. 13—MANIFOLD DESIGN IN WHICH THE INTERSECTION OF THE BRANCH WITH THE MAIN MANIFOLD IS HIGHER THAN THE INTERSECTION OF THE CENTER PORT

This Condition Will Feed a Greater Proportion of Wet Ends to the Branches than to the Center Port. This Variation in the Height of Intersection Serving as a Means of Calibrating the Distribution between Branches

I regret that I am unable to show a perfect fishhook. Such a curve would necessarily represent perfect distribution, which I do not believe exists. Of course, a mixture fishhook taken from a single cylinder set-up would represent the characteristics of perfection. I therefore regret that I could not present single-cylinder data.

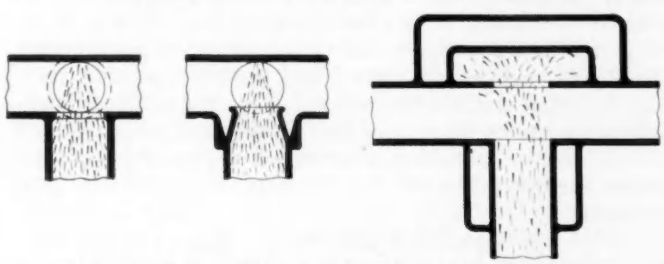


FIG. 14—SOME FORMS OF RISER CONSTRUCTION

The Design at the Left Is Somewhat Difficult to Manufacture and Depends upon Its Concentricity for Proper Functioning. Although the Design Illustrated in the Center Has the Appearance of Being Very Efficient, It Is No Better than a Straight Intersection. The Design Shown at the Right Gives Very Inconsistent Performance, Permitting Wet Fuel To Drop Back Intermittently into the Manifold of Air

Thus a combination of comparative graphs and common-sense deduction is offered. The graphs tell how much, and the deductions, where.

PART 2—DISTRIBUTION

In this division of the paper it is not proposed to outline completely all the possible failings of the induction system. However, I shall discuss a few of the problems that are met every day in the hunt for the all-evasive perfect distribution. Thus I hope to inspire engineers by example or protest to bring forth their methods and opinions.

The Carbureter

Let us begin with the carbureter, the engineer's perpetual alibi, the imaginary root of all operating ailments. Poor distribution is the most undeserved of the many difficulties that we blame fallaciously on the carbureter. Regardless of what can be rightly placed at the door of the carbureter, much more fault can be, and is found in the parts between the carbureter and the valves.

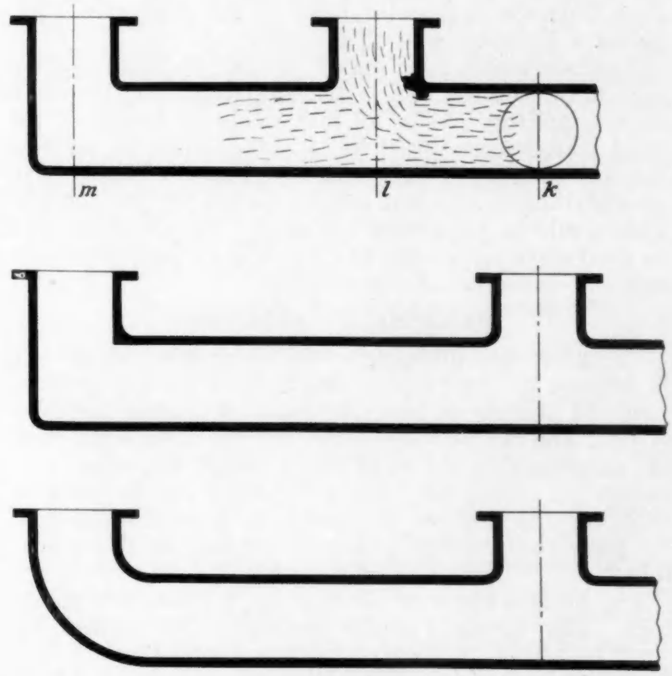


FIG. 15—THREE EXAMPLES OF MANIFOLD-BRANCH DESIGN

At the Top That for a Four-Port Six-Cylinder Is Shown, with a Branch for a Three-Port Six-Cylinder Manifold Directly Below. The Bottom Drawing Illustrates a Manifold End for Use with a Port Insert

The degree of atomization differs among makes of carbureter, perhaps because of the varying methods of mixing the air and fuel. An induction system that is sensitive to a wet mixture will do better with the improved atomization. We have found conditions where the air horn of the carbureter was improperly blended into the mixing bowl, resulting in a tendency to force the mixture to one side. Under these conditions the lean cylinders were at one end of the engine or the other, depending on whatever way the carbureter was

turned. The mixture-fishhook characteristics were the same under these conditions. However, after leaning down the mixture, we could readily locate the weakness that followed the carbureter. An ideal construction would permit air to be fed centrally into the mixing chamber from underneath.

Throttle-Plate Deflection

Evidence of the throttle-plate deflection has been submitted and the fact brought out that some makes of carbureter are not sensitive to throttle-shaft position. Throttle-plate deflection of the mixture is, I believe, caused by incorrect initial mixing of the air and fuel. If the fuel is concentrated in the center of the airstream below the throttle-plate, as shown at the left in Fig. 9, the heavy mixture is deflected when it strikes the throttle-plate. If the fuel is fairly well concentrated around or near the outer edge of the airstream, it will tend to clear both sides of the throttle-plate, as shown in the central view. Some makes of carbureter include a hop-off. This construction, shown in the view at the right, is intended to force the wet fuel from the carbureter riser to the airstream. Experience indicates that this is effective.

Fundamentally, the major project in manifold design is to keep the fuel in the airstream. If this could be accomplished easily, all that would be necessary for good distribution would be to obtain uniform air-flow through each leg of the manifold. Then we should have no distribution problem and no papers on the subject. This would be altogether too good. The chief enemies to good distribution are (*a*) a poorly divided airstream and (*b*) uncontrolled precipitation.

Balancing the Airstream

The airstream division is worthy of much study. It is affected by the varying length of arms due to friction, the number of bends or turns it travels, the type of bend and the velocity of the air. It is essential that the airstream should be balanced before any other correction be attempted. The air balance can be checked with varying degrees of exactness, from comparative compression-pressures to actual air-flow in the manifold.

Fig. 10 is a chart of air-flow for a three-port manifold. The curves indicate resistance to air-flow in

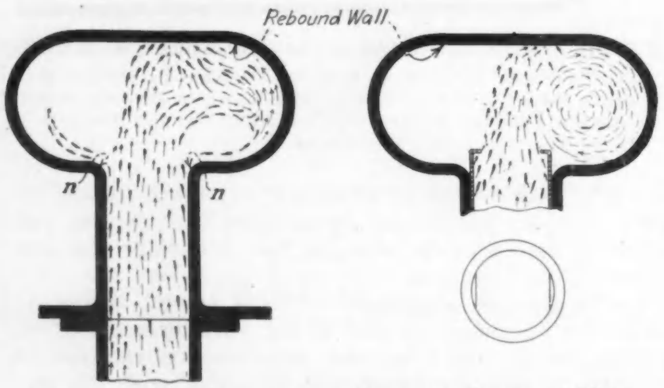


FIG. 16—EXAMPLES OF THE USE OF A REBOUND WALL

This Wall Is Not Heated and Is Effective in Minimizing the Tendency of the Wet Fuel To Flow to the Inside Wall. The Corners at *n* Are Seldom Sharp Enough To Be Effective in Discouraging Wet Fuel from Following around the Wall. Use of a Port Insert, Such as That Shown in the View at the Right, Forces the Wet Fuel Back into the Airstream and Permits the Corners to Be Rounded Sufficiently To Permit a Better Air-Flow

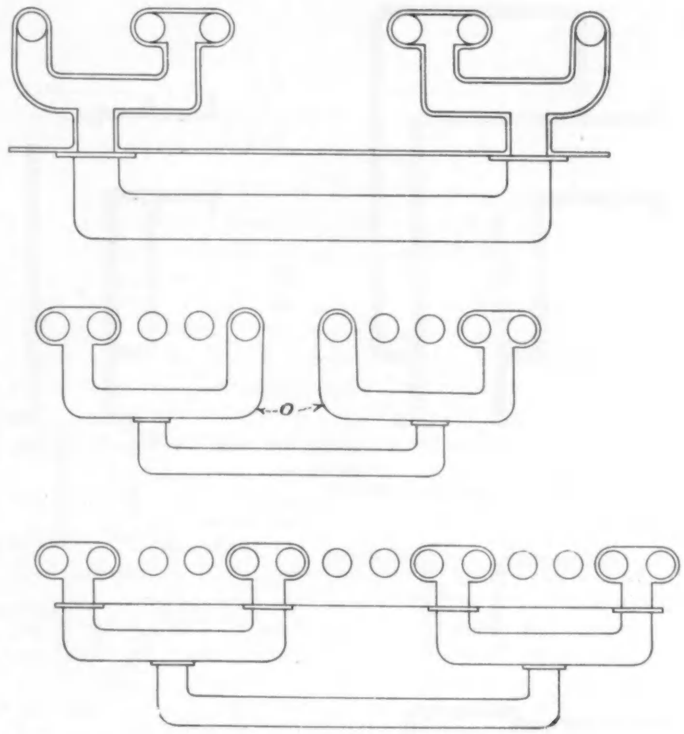


FIG. 17—SOME TYPES OF MANIFOLD

In the Two-Port Six-Cylinder Manifold Illustrated at the Top, the Portion Outside of the Cylinder-Block Is in Two Parts and Is Very Simple To Make, the Complications Having Been Transferred to the Cylinder-Block. The Middle Drawing Illustrates a Four-Port Six-Cylinder Manifold in Which the Pipe Is Not in the Cylinder-Block and Can thus Be Readily Modified for Balance. In the Eight-in-Line Manifold Shown at the Bottom the System of Piping Lends Itself to Air-Balancing, the Connecting Pipe Can Enter the Two Intermediate Pipes from Any Direction, and the Port of Entry Can Be Modified To Calibrate Distribution When Symmetry Fails

inches of mercury. The air is given in cubic feet per minute. The upper full-line curve represents the resistance of the long arms, the developed length of which is approximately $12\frac{1}{4}$ in. and the inside diameter is $1\frac{1}{8}$ in. The lower full-line curve represents the resistance of the short arm, the developed length of which is $3\frac{1}{2}$ in. and the inside diameter is also $1\frac{1}{8}$ in. Fair distribution is impossible with a resistance difference as indicated here. The dotted curves give some idea of the dimensional change necessary to balance the resistance of the air-flow. We find that $\frac{7}{8}$-in. inside diameter of the short arm is equal to $1\frac{1}{8}$-in. inside diameter of the long arm, this difference being due to the friction of the long arm. To reduce the center-port diameter sufficiently to compensate is seldom possible, as the volumetric efficiency would suffer. Obviously, the change should be in the long arm, the diameter of which should be increased. However, this requires consideration because the lowering of the velocity will promote precipitation.

Manifold and Valve Size

Consideration should be given to the manifold size in conjunction with valve size, cam timing and engine range. A maximum velocity through the pipes is needed for good low-end performance and the driest manifold. The greater the velocity is, the more wet fuel is picked up by the air in motion.

An excellent practice would be to have a valve ca-

pacity that would give a high-speed range in excess of that desired and then limit the top range to the point required by decreasing the manifold area. In this way the restriction is in the pipe, which is as it should be. This condition gives a certain amount of leeway in balancing the air-flow.

What can be accomplished by stepping-up the volumetric efficiency at every point other than the manifold is surprising. I recall a case in which more horsepower was obtained with a 1-in. manifold than with one 5/32 in. larger in diameter. Other parts in the engine were changed to permit this increase in power. The beneficial effects of the small manifold were gratifying.

Heat-Application Methods

Precipitation is the most difficult problem with which we have to deal. To overcome this, we find a multitude of hot-spots in addition to many points of design. The application of heat can be divided into (*a*) heated air, (*b*) heated riser and (*c*) heated riser and T.

Heated air is, we believe, the least beneficial for any system of raising the mixture temperature. It does not lend itself to permanent year-round installation, except as an accessory to some other form of heat and should be thermostatically controlled for climatic or temperature changes. This method, we understand, is recommended by Whatmough.

Heating the mixture through the riser is not as beneficial as heat applied at the T. However, both are more effective than heated air, because they come into action at the first point of precipitation, which is at the riser, and at the first point at which the fuel leaves the airstream, which is at the T.

Heat applied at the T is the most beneficial, because it may form a hot rebound spot or plate for the fuel that leaves the airstream. Thus the heat is applied to the fuel rather than the air.

Mixture temperatures do not always reflect the quality of the mixture. For instance, the quality of the mixture at 120 deg. fahr. heated at the T may be better than the quality of a mixture heated at the riser to 130 deg. fahr. because the homogeneity of the fuel is improved by rebounding the heavier ends from a hot-spot.

Fuel That Leaves the Airstream

Having discussed the necessity of dividing the air equally to control the volume of fuel-laden air that will flow in each direction, we must now consider the fuel that leaves the airstream and how to reabsorb in the air as much of it as possible. Let us assume that the riser enters a four-way branch, as in Fig. 11. We know from experience that the air, assuming an air balance, will follow equally in any one of the four directions, because the air is being dragged definitely from one direction or the other, or it would not move at all. However, the wet fuel behaves differently and, unfortunately, is not consistent in its habits. If we were dealing with consistency, I am sure we could provide for its behavior and guide the wet fuel back into the airstream. We must work with the obvious, and obviously a portion of the wet fuel will leave the air at the T. If we provide a rebound surface above the riser, undoubtedly a portion of the wet fuel will bounce back into the airstream, which is presumably balanced, and follow its direction. If this surface is heated, the rebound is aided, because the fuel particles are more or less exploded from the hot surface.

We can imagine no difficulty in division of the air in a four-branched pipe. Why, therefore, should we be dubious about the same pipe with one branch eliminated? This brings us to the present-day three-port manifold as used on many six-cylinder engines.

In discussing air balance the possibility of reducing the center-port size or increasing the size of the side arms was mentioned. General conditions will dictate where the compromise is to be made, but under either condition the intersecting area at *i* in Fig. 12 will be smaller than at *j*. This means that more wet fuel may find its way into the intersection of largest area and, as we know by experience, we can have lean center-ports, assuming that adequate rebound-surface is provided above the riser. This would be a very healthy condition, because it offers leeway for correction as shown in the drawing at the right. Here we see the rebound wall shaped to guide wet fuel into the center port. The extent of the curvature of the rebound wall is dependent upon the demand of the center port.

Meantime, we have to deal with that portion of the wet fuel that leaves the airstream in the riser and climbs along the walls, finding its way into the arms of the manifold. Minimizing the quantity of wet fuel that collects on the lower side of the branches is important, since this is the hardest fuel to pick up. Precipitation at the top walls will drop off or be easily picked off by the moving mixture. This condition can be helped by avoiding round corners at the intersection of the riser and the branches; in fact, reversing the condition slightly as shown in Fig. 12. This will tend to direct the wet fuel back to the air or to the rebound wall.

Dividing the Wet Fuel Accurately

Another point for consideration is the promotion of accurate division of the wet fuel at the T. This can be aided by care in the location of the intersection of the individual branches. Fig. 13 indicates a design with the branch intersection higher than the intersection of the center port. This condition will feed a greater proportion of wet ends to the branches than to the center port. In fact, this variation of the intersection can be used as a means of calibration between branches.

Many freak designs have been built and tested by all of us in an effort to control initial division of the mixture. Fig. 14 illustrates some of them. The design illustrated at the left is somewhat difficult to manufacture. Its functioning depends upon its concentricity. The design shown in the center is somewhat expensive. Although very efficient in appearance, it is really no better than a straight intersection. The design that everybody tries sooner or later, only to find that its promise is never fulfilled, is illustrated at the right. It is the most inconsistent performer of all. Evidently it acts as a collector, and as such permits wet fuel to drop back intermittently into the manifold or air, overloading the mixture in the direction in which it is carried.

Let us follow the mixture along the manifold into the branches. Fig. 15 indicates one branch of a four-port six-cylinder manifold, one branch of a three-port six-cylinder manifold and a manifold end for use with a port insert. My own opinion is that the top sketch represents a condition that is very difficult to correct. However, perhaps discussion will bring out a remedy. Obviously, fuel will leave the airstream at this turn

and, as no rebound occurs, the wet fuel will pass the port until picked up by the mixture moving toward the end. In addition, we must bear in mind that the manifold-metal temperature is seldom sufficient to prevent precipitation. Therefore, fuel is leaving the airstream throughout its movement in the pipe. As the length of wet pipe between k and l is considerably less than between l and m, we find that a bad condition is made worse. We believe that every turn should be aided mechanically. The end turn in the manifold shown in the middle sketch, which is used in conjunction with siamesed ports, is the most discussed point in manifold design. The consideration here is how to make the turn with the minimum interference with volumetric efficiency and least detrimental effect on distribution.

Keeping the Fuel Off the Walls

Good flow-lines or a long bend are shown in the drawing at the bottom in Fig. 15. Good distribution construction is shown in the drawing at the top. This is an old story, and we all know that the pressure of the air-flow in the long bend forces the wet fuel over to the inside of the bend. With the square corner, this condition is mitigated, because we provide a rebound wall. This wall is not heated, but we know from experience that it is effective in minimizing the tendency for the fuel to flow to the inside wall. Frequently this effect is overdone, and the wet fuel tends to stay with the outside wall, thus destroying the value of the correction. Unfortunately, squaring up the corner is not reliable in itself because the wet ends that are theoretically supposed to be in the center of the airstream, due to rebound, are intermittently flowing from side to side of the port wall and may upset distribution.

The corners at n in the left view of Fig. 16 are seldom sharp enough to be effective in discouraging the wet fuel from following around the wall. However, we can provide some form of insert to perform this function. An insert is shown at the right where the wet fuel is forced back into the airstream. With such a port insert, the manifold can be stepped back and the corner rounded sufficiently to permit a better air-flow. The corrective burden is then placed upon the port insert, which, if properly designed, is well able to take up the load. Port inserts can be designed in many different ways. However, two all-important conditions should be borne in mind: The design must be such as to deflect the wet fuel from its sides to the airstream, and it must not restrict air-flow to such an extent that volumetric efficiency is decreased. As it need only be effective at the sides, the top and bottom can be open.

Following the principle of aiding the turn at each point, we must aid the last turn of the mixture, which is at the valve. A rebound wall is provided to bounce back into the stream the wet fuel that leaves the air. This the flat wall does for either side. This procedure should be followed out for all siamesed ports.

It is our opinion that the principles outlined herein can be applied to manifolds, regardless of the number of cylinders involved. Further, assuming all other elements of function to be correct, these principles will serve to improve distribution. Fig. 17 illustrates the point that these general principles can be applied to various types of manifold; in fact, these principles are being applied.

Application of Principles to Manifold Design

The drawing at the top is of a so-called two-port six-cylinder manifold that is certainly not all its name implies. The manifold outside of the cylinder-block is two ports and very simple to make. However, the complications have been transferred to the cylinder-block. This set-up incorporates five major divisions, and, although it eliminates consideration of a three-way T, we believe that it involves the necessity for great care. Examination of this design indicates that its detail can be treated by the method outlined in this paper. A manifold built into the block undoubtedly complicates the major casting and in addition makes an efficient thermostat essential, because so much of the pipe is surrounded by water.

The middle drawing in Fig. 17 indicates a four-port six-cylinder manifold. Obviously, the mechanics of this type are similar to those of two-port type. The difference lies in the fact that the pipe is not in the block and thus can readily be modified for balance. Squaring-up the corner at o to balance the air-flow at this point against the end ports may be necessary. The intersection of the connecting pipe with the intermediate pipe can be moved for calibration when symmetry fails. This occurs when harmful pulsations are present in the manifold. The influence of pulsation may serve to upset the distribution to such an extent that ordinary correction will not avail. The causes of pulsation most frequently experienced are blow-back through the valves and the natural surge of the mixture moving from one end of the manifold to the other. These two sources must be worked out sufficiently to compensate for the evil they do.

The drawing at the bottom indicates how the principles mentioned can be applied to eight-in-line manifolds. This system of piping lends itself to air-balancing, provided no two cylinders which are fed from one leg of the manifold fire 90 deg. apart. The connecting pipe of the manifold can enter the two intermediate pipes from any direction and, further, the point of entry can be modified as a means of calibrating distribution when symmetry does not satisfy. For example, should we desire to enrich the end cylinders, we should move the intersection toward the center of the engine to provide a greater length of wet pipe to feed more fuel to the desired cylinders. The reverse is true when the inner cylinders are lean.

A formal conclusion to this paper is omitted in the hope that this is but a beginning and that discussion and dissemination of information on the fundamentals of distribution routine will continue. Nothing new has been presented herein; I have merely reiterated known facts, which include (a) a method of charting distribution progress, (b) a suggestion for locating the error and (c) a series of thoughts on construction.

THE DISCUSSION

CHAIRMAN F. C. MOCK[2]:—I am impressed not only with the quality of Mr. Taub's development work but also with the considerable quantity of intelligently planned and conducted research work that this paper reports. One of the things that he emphasized, and that I hope will be considered in the following discussion, is the need of a common method that can be followed generally by all those working on this same problem. The

[2] M.S.A.E.—Engineer, Bendix Aviation Corp., South Bend, Ind.

method of plotting by fishhooks seems to depict, better than anything else I have seen, the economy characteristic of any given set-up of carbureter, manifold and engine. If anyone here has a better method of plotting, or constructive criticism applicable to this one, I hope it will be brought out.

Another thing that is perhaps novel in our American practice is the use in these curves of the mixture ratio, which involves measuring the air-flow to the engine as well as the fuel-flow. This is advisable for many reasons but it has been ignored in the past chiefly because it seemed a big task. I believe that developing a convenient, quick-reading method of measuring the air-flow to the engine is worthwhile and that we shall soon find that this procedure, instead of taking more time, would save time in our development work. Such determination of air-flow is particularly desirable in measuring the performance of the engine at light loads. With our present-day high-performance automobiles, we have reached a point where at 20 m.p.h. level-road driving we are using little more torque than to idle, so that in such study the occasionally varying friction horsepower of the engine is a very disturbing element. Under such conditions, material gain in accuracy will result from measuring the intake-manifold depression and the air-flow to the engine and making comparisons by mixture ratio rather than by fuel consumption and developed power.

Analytical Value of the Fishhook

R. N. JANEWAY[3]:—This paper forcibly brings home the fact that the study of mixture distribution can be most readily attacked by making the engine testify

[3] M.S.A.E.—Consulting engineer, Detroit, Mich.

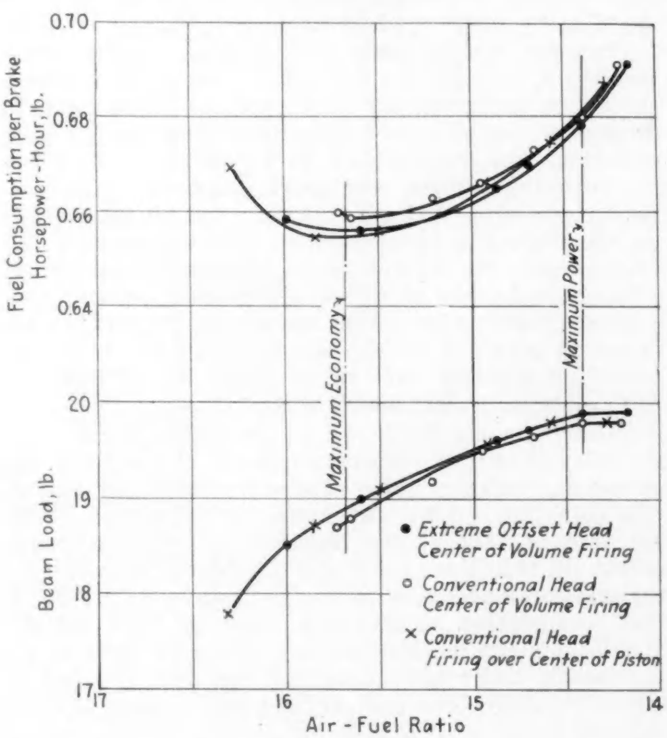


FIG. 18—THREE FISHHOOKS OBTAINED WITH A 3½ X 4-IN. SINGLE-CYLINDER L-HEAD ENGINE AT 1000 R.P.M. AND FULL LOAD

These Were Secured with Three Different Combustion-Chamber and Firing-Position Combinations

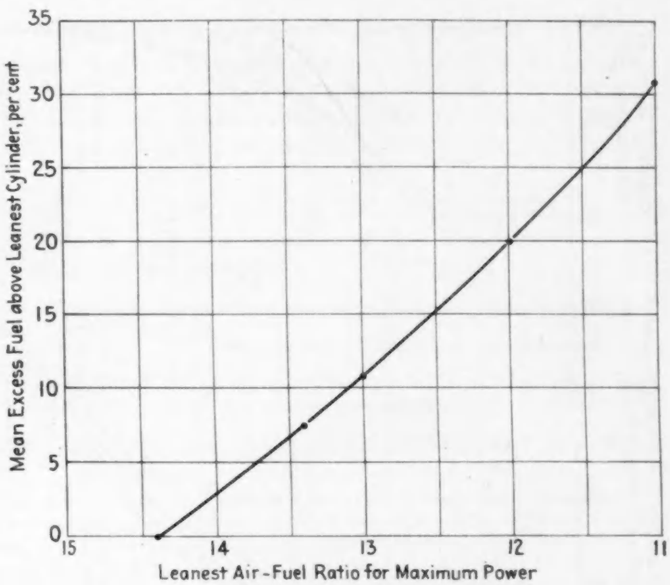


FIG. 19—MEAN EXCESS DISTRIBUTION PLOTTED AS A FUNCTION OF THE LEANEST AIR-FUEL RATIO FOR MAXIMUM POWER

against itself. The tell-tale fishhook that Mr. Taub has so ably described provides not only the best relative measure of the nature of distribution but also can be made to yield very definite quantitative information as to the extent of departure from uniformity of mixture proportions among cylinders.

The real value of the fishhook for analytical purposes lies in the fact that it necessarily refines the conditions of maximum power and maximum economy. To be really useful these conditions must be defined in terms of air-fuel ratios. To this extent I should recommend an amendment to Mr. Taub's method of plotting his curves against relative total fuel-consumption at full load. I emphasize this because the full-load fishhook is particularly useful in obtaining a quantitative measure of distribution.

To obtain maximum power at full load from an engine having varying mixture proportions among cylinders, the leanest cylinder must have at least the leanest mixture for maximum power-development, the remaining cylinders consequently having mixtures of varying degrees of over-richness. The minimum total fuel required for maximum power is thus governed by the requirements of the leanest cylinder and will vary in direct proportion to the mean per cent excess above the leanest cylinder. For example, if in a six-cylinder engine, five cylinders received the same quantity of fuel but one received 20 per cent less, taking the quantity received by the leanest cylinder as 1, each of the five remaining cylinders received 1.2. The total excess above the leanest cylinder is thus 5×20 or 100 per cent and the mean excess is $100 \div 6 = 16.67$. In this case 16.67 per cent excess total fuel must be supplied to obtain maximum power and the resultant over-all air-fuel ratio will be 16.67 per cent greater than that inherently required for maximum power by any one cylinder. If this inherent mixture-ratio is known, the leanest mixture-ratio for maximum power as defined by the fishhook will give the mean excess variation among the cylinders by simple proportion.

The single-cylinder engine obviously supplies the

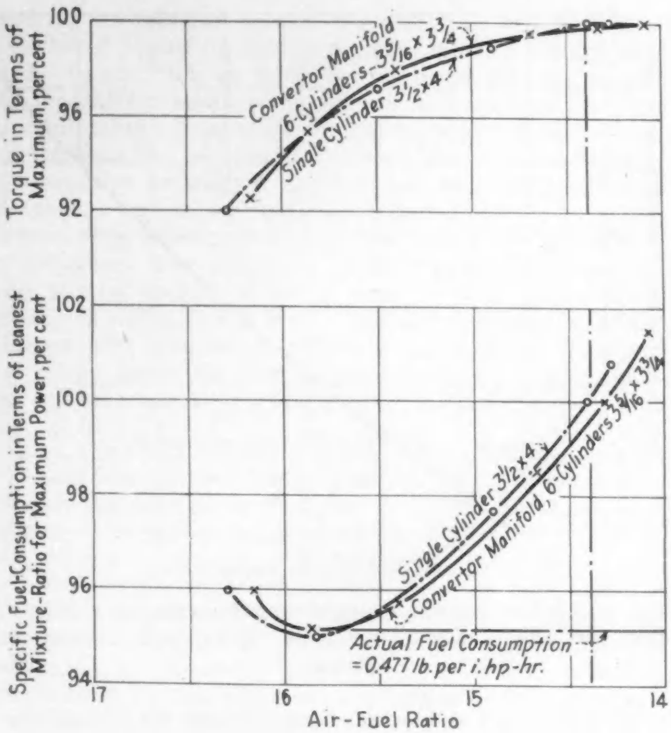


FIG. 20—FISHHOOKS SHOWING PERFECT DISTRIBUTION

These Curves Were Obtained on a 3 5/16 x 3¾-In. Six-Cylinder Overhead-Valve Engine at 1000 R.P.M. and Full Load and Are Superposed upon One Set of the Single-Cylinder Curves of Fig. 18. The Almost Complete Agreement of These Curves, Especially with Regard to the Mixture Ratios at the Leanest Point for Maximum Power and at Maximum Economy, Is Obvious

criterion for inherent mixture-ratio requirements since it involves no distribution problem. Fig. 18 shows three fishhooks obtained from an L-head 3½ x 4-in. single-cylinder engine at 1000 r.p.m. and full load with three widely different combustion-chambers and firing positions. In all three cases the leanest air-fuel ratio for maximum power is 14.4 to 1. This ratio seems to be inherent for conventional-type engines and independent of combustion-chamber variables. Then, if we take 14.4 as the ideal mixture-ratio for 100 per cent uniform distribution, the mean per cent excess variation will be 14.4 divided by the air-fuel ratio required for maximum power. Fig. 19 shows the variation of mean per cent excess with leanest air-fuel ratio for maximum power.

Ideal Fishhook Produced with Fuel Converter

Mr. Taub apologized for being unable to show the ideal fishhook. I am happy to accept his apology but I am also glad to be able to show the ideal fishhook obtained on a six-cylinder 3 5/16 x 3⅜-in. overhead-valve engine at 1000 r.p.m. and full load. Fig. 20 shows this fishhook superposed upon one of the single-cylinder curves of Fig. 18, the specific fuel-consumption being plotted as a percentage of the leanest mixture-ratio for maximum power. The almost complete agreement of the two curves is obvious, especially with regard to the mixture ratios at the leanest point for maximum power and at maximum economy. Needless to say, this ideal distribution has not been achieved by any mere modification of conventional manifolding. This is the result of an entirely new departure in manifolding which is being developed by my client, the Automotive Devices Corp., by whose courtesy these data are being presented.

I regret that the details of the fuel converter cannot be divulged at this time. However, I may say that it operates by absorbing the liquid fuel out of the air-stream and vaporizing it by the concentrated application of heat, which avoids unnecessary heating of the air. Thus a dry mixture is secured without any sacrifice of volumetric efficiency. By eliminating the various expedients that are ordinarily required for distributing wet mixtures, the fuel converter makes possible an appreciable gain in volumetric efficiency in addition to achieving its primary object, which is uniform distribution.

Criterion for Part-Load Efficiency

The determination of an absolute criterion for part-load efficiency is more difficult because the mixture ratio required for maximum economy at constant load and variable throttle is not a significant measure even of relative distribution. Fig. 21 shows a series of three fishhooks taken at 1000 r.p.m. with a constant output of 5 hp. corresponding to about 22 per cent of full load. That these three curves represent a wide divergence in the nature of distribution is apparent, yet the maximum economy in all three cases occurs at approximately the same mixture ratio. These curves were obtained on the same engine referred to above in connection with the ideal full-load fishhook. The top curve was obtained with the standard manifold without port inserts, and the middle one shows the striking improvement made by the addition of port inserts in the same manifold. The bottom curve was obtained with the converter manifold and shows an even greater gain in economy over the middle curve than the latter represents over the top one. As the distribution is improved, not only is the actual fuel-consumption greatly reduced but the shape of the curve approaches closer to a real fishhook.

Since the mixture ratio at maximum economy is not sensitive to changes in distribution under constant load, the actual maximum economy must be relied upon to determine the extent of departure from perfect distribution. For this purpose the engine should be given the advantage of the best spark-advance for the particular condition, and the fuel consumption determined on the indicated horsepower by measurement of the friction with the throttle set at the point of maximum economy and other conditions duplicating as nearly as possible those under actual operation. In this way a figure is obtained which can be compared with the maximum economy that is, or would be, obtained at full load with perfect distribution.

Referring again to Fig. 19, we see that, with the ideal condition of perfect distribution, maximum economy occurred at a mixture ratio of about 16 to 1 and that at this point the specific fuel-consumption was about 95 per cent of that at the leanest point for maximum power. If at a given speed at full load the leanest mixture-ratio for maximum power is known, the potential fuel consumption at maximum economy with perfect distribution can be calculated by taking 95 per cent of the specific fuel consumption that would be obtained if maximum power occurred at an air-fuel ratio of 14.4 to 1 or

$$E_p = E_m \, (R/14.4) \, 0.95$$

where

E_m = actual specific fuel-consumption at leanest mixture for maximum power

E_p = potential maximum-economy for perfect distribution
R = leanest air-fuel ratio for maximum power

This potential maximum indicated-economy, although obtained at full load, can be used as a criterion for part loads because the inherent indicated efficiency of the engine is independent of load. This is not only theoretically true according to the thermodynamics of the engine cycle but appears to obtain in practice. Fig. 22 shows the indicated fuel consumption at maximum economy obtained at 1000 r.p.m. with varying load on the six-cylinder 3 5/16 x 3¾-in. engine with the converter manifold. From full load down to about 45 per cent of load, the fuel consumption is constant and corresponds to the potential maximum economy as defined by the perfect full-load fishhook shown in Fig. 20. As the load is reduced below 45 per cent, the curve shows a tendency toward an increased fuel consumption, but at 23 per cent of full load the fuel consumption is only 4 per cent greater than the potential minimum.

The data herein presented on the converter manifold have been limited to illustrations of what is believed to be a new method for gaging distribution, namely, the application of a yardstick representing at least approximately the potential efficiency of the engine with perfect distribution. However, the principle involved in the converter is believed to make possible the practical solution of the long-fought problem of distribution. I hope that in the near future complete data on this device can be presented before the Society.

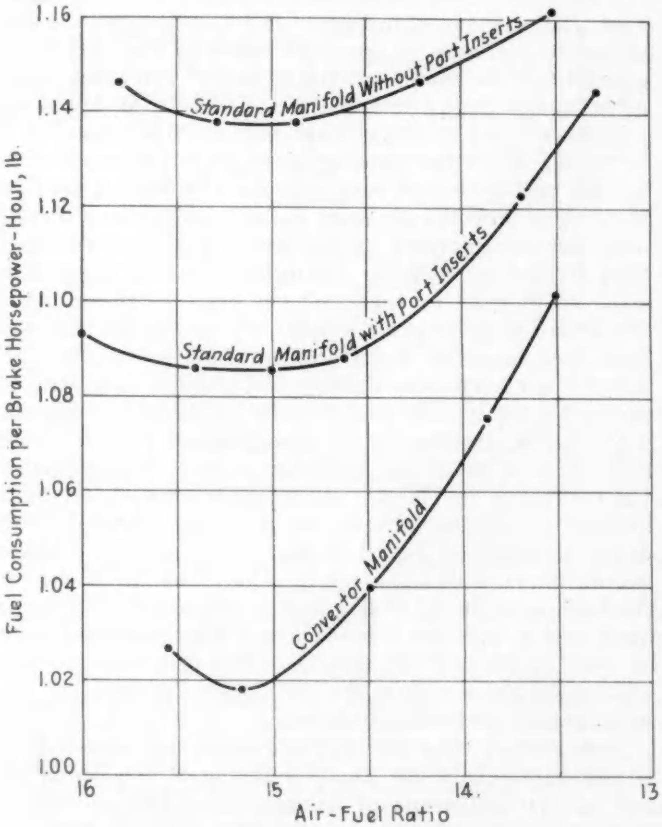


FIG. 21—A SERIES OF ROAD-LOAD FISHHOOKS

These Curves, Which Represent a Wide Divergence in the Nature of Distribution, Were Taken at a Car Speed of 20 M.P.H. and an Engine Speed of 1000 R.P.M. with a Constant Output of 5 Hp. Corresponding to About 22 Per Cent of Full Load. The Different Manifolding Arrangements Are Indicated on the Curves

Janeway Set-Up Worth Analyzing

ALEX TAUB:—The amendment to fishhook procedure that Mr. Janeway offers is a fair one, particularly since a 14.4:1 air-fuel ratio represents par for fuel efficiency. With this point known and the air-fuel ratio for the leanest point for maximum power established on the fishhook, we can, as he points out, determine the quantitative picture of the mean variation.

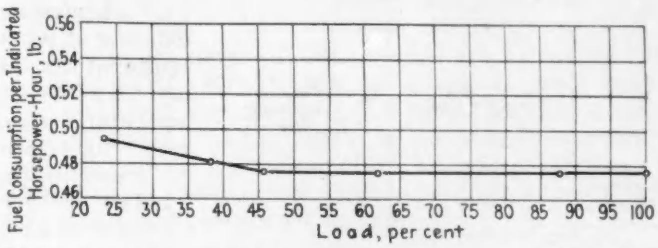


FIG. 22—INDICATED FUEL-CONSUMPTION AT MAXIMUM ECONOMY PLOTTED AGAINST LOAD

The Points from Which This Curve Is Plotted Were Obtained at 1000 R.P.M. with Varying Load on a 3 5/16 x 3¾-In. Six-Cylinder Engine with the Converter Manifold

I am pleased to acknowledge Mr. Janeway's perfect fishhook. He shows a curve made from a multi-cylinder engine that coincides with his single-cylinder curve. Little doubt can exist that the set-up to obtain this agreement must be operating with perfect, or at least most excellent, distribution. The mechanism he uses is worth analyzing and is certainly interesting because, if some form of heated metallic absorbent can be introduced into the riser, it would soak up the heavy wet ends and due to its temperature would convert this uncontrollable portion of the fuel into a gas or vapor that would follow the airstream.

Mr. Janeway's remarks on the necessity of using specific fuel-economy as the variable for determining fuel consumption for car-driving loads may be considered as well taken. However, we must bear in mind that, although the air-fuel ratio is practically a constant at the maximum-economy point, yet, using the original combination as a basis and taking the air-fuel ratio at the maximum-economy point, we find (See Fig. 7) 14.5 to 1 at 0.983 lb. per b.hp-hr. fuel consumption. The air-fuel ratio at which this fuel consumption of 0.983 lb. per b. hp-hr. is obtained in the curve indicating the modified set-up is 13.3 to 1. Thus we establish the fact that the original set-up would require to be leaned off 1 whole air-fuel ratio to obtain the equivalent mileage of the modified set-up. This comparison serves to bring home why the original set-up would be ragged in operation and the modified set-up would be smooth.

Mr. Janeway uses the maximum-economy point in his deductions for part-load distribution. He may be justified in so doing with his converter; however, with conventional manifolds of any design, operating at maximum economy is usually impossible due to ragged running of the engine. Usually a point on the strong side of the curve, which is the rich side, must be selected and at this point the engine will run steadily.

CHAIRMAN MOCK:—One difficulty in harmonizing what we find in the laboratory and on the road apparently is due to the difference in temperature conditions. With varying temperatures the fuel may pass through the manifold as a river, a spray, a fog or a vapor. In each of these conditions it may behave differently at

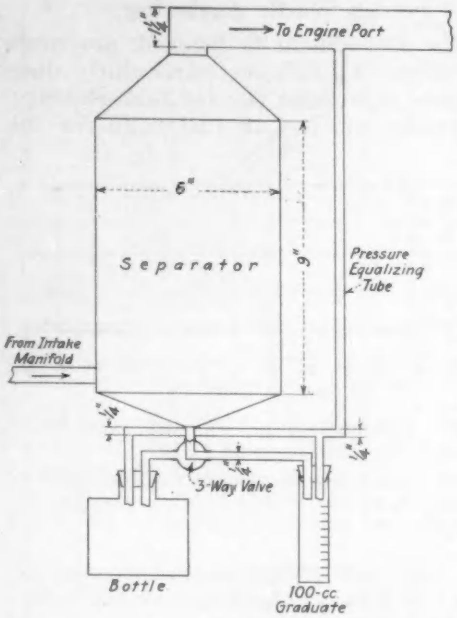


FIG. 23—SEPARATOR SET-UP USED IN MIXTURE-DISTRIBUTION TESTS AT THE UNIVERSITY OF ARKANSAS

the same bend of the manifold, with the same air-flow. For instance, I have often found that the phenomena existing at room temperature, as in the test laboratory, are very uncertain of repetition under another temperature, such as might exist under the hood on a fairly warm day. This thought may help to harmonize the statements of our different speakers.

L. C. PRICE[4]:—The Engineering Experiment Station at the University of Arkansas has for some time been investigating the problem of fuel distribution in a six-cylinder engine having three intake-ports. In connection with Mr. Taub's very excellent paper, a brief summary of our results may be of interest.

Our methods have been essentially the same as those recommended by the author in that we have used economy curves to show the improvement effected. The difference lies in our use of separators, as shown in Fig. 23, to find where the distribution is at fault, instead of locating the weak cylinders, as suggested in the paper. We were able thus to recover slightly more than one-half of the gasoline that went to the carbureter. Since our engine has three intake-ports, the installation of separators between the manifold ports and the engine ports has confined the investigation to distribution among the three ports rather than among the six cylinders. We admit that flow conditions in the manifold when the separators are installed and the engine is motored over with the dynamometer are not the same as in ordinary running under power, yet, in every case where we were able to effect an improvement in distribution as shown by the separators, the economy of the engine when running under power, at the same speed and throttle opening, was improved also.

The liquid collected at each separator, however, is an index only of the quantity of fuel fed to that engine port and is a measure of the relative mixture-strength only if the manifold supplies equal quantities of air to the several ports. Mr. Taub has pointed out that, because of the extra resistance set up by the bends and extra lengths of the end branches, they should be made larger than the center branch. This, it seems to me, is the logical starting point in any study of distribution; namely, to design the manifold so that the branches will supply equal quantities of air to the engine ports. Only in that case will all cylinders develop equal power even if the fuel distribution is perfect.

The engine used in our tests came from the factory equipped with a Swan manifold having a hot-spot at the T on the side next the engine. A new exhaust manifold was made and short pipes were installed to move the intake manifold out from the engine so it would run cold. If the distribution and economy can be improved with a cold manifold, obviously the proper application of heat will effect a still further improvement. Hence, all our tests, both for distribution and under power, were made with the intake manifold cold.

Distribution tests were first made with the stock manifold, the carbureter air-horn was turned rearward, the float bowl and idling jet being in ront, and the throttle shaft was perpendicular to the engine. At once we found that, with the throttle nearly closed, the forward cylinders were richest. As the throttle was opened, the region of richness moved toward the rear until at full throttle the rear cylinders were over-rich.

This non-uniformity of mixture as it came from the carbureter was worse at full throttle than at idling and became still worse at higher speeds. These results were checked with a different make of carbureter and were found to be substantially the same. Each of these carbureters has a rather sharp turn where the air-horn enters the vertical mixing chamoer.

Effect of Carbureter Air-Horn Position

Turning the carbureter to different positions showed that with any given speed and throttle opening the condition of richness or leanness followed the carbureter around. This modification, however, referring hereafter to conditions of half-load and above at 450 r.p.m. and down to 15 or 20 per cent load at 2000 r.p.m., must be made. With the air horn away from the engine, the middle port was very lean and the end ones somewhat rich, while with the air horn toward the engine the richness was concentrated on the center port and the leanness divided between the end ones. Since the carbureter adjustment must be such that the leanest cylinders will fire steadily under road conditions, our conclusion was that best economy would be obtained when the carbureter air-horn was toward the engine. As will be shown presently, this was actually found to be the case.

Professor Jacklin, in a paper presented at the 1929 Semi-Annual Meeting, described a manifold extension for mounting just above the carbureter and having a number of annular grooves on its inner surface[5]. This device is shown in Fig. 5 of that paper, and its purpose was to improve distribution by equalizing the fuel-flow. We made a duplicate of this device and tested it both for distribution and under power along with the other tests at 1600 r.p.m. and full throttle. The rich mixture was still on the same side as the carbureter air-horn but not in as great a degree as before.

In our work thus far we have made and tested 8 or 10 different manifolds, finally arriving at one which we will call the University of Arkansas manifold and which is shown in cross-section in the insert on Fig. 24. It was made of welded sheet metal 1/16 in. thick and is square rather than round simply because that shape was easier to make. The end branches are $1\frac{3}{8}$ in. square and the middle branch is $1\frac{1}{4}$ in., being made so by

[4] M.S.A.E.—Research associate professor of mechanical engineering, University of Arkansas, Fayetteville, Ark.

[5] See S.A.E. JOURNAL, November, 1929, p. 526.

dropping the top wall 1/8 in. and closing in the side walls 1/16 in. each, while the bottom is on the same level as that of the end branches. Distribution tests at 1600 r.p.m. and full throttle, with carbureter air-horn toward the engine, showed this to be the best design thus far tested. Apparently the drop in the top wall serves as a dam that keeps some of the rich mixture from the center port. Tests under power at the same speed and load confirmed the distribution tests.

Fig. 24 shows some power curves for the engine at 1600 r.p.m. and full throttle. Specific fuel consumption is plotted against brake horsepower, so that one curve for each condition tells the whole story. Each point on any given curve represents a carbureter needle-valve setting. Curve No. 1 was obtained with the stock manifold and the carbureter air-horn turned toward the rear. Insertion of the Jacklin device between carbureter and manifold improved matters, as shown in Curve No. 2. The next curve was obtained with the stock manifold and the carbureter air-horn turned toward the engine. Again the addition of the Jacklin device improved matters, as shown in Curve No. 4. Curves Nos. 5 and 6 were obtained with our own manifold, first without the Jacklin device and afterward with it. These two curves cross, Curve No. 5 showing better power and better economy as a maximum-power mixture is approached. Just now, I have no explanation for this except that it may be due to the very slight volumetric loss in the Jacklin device.

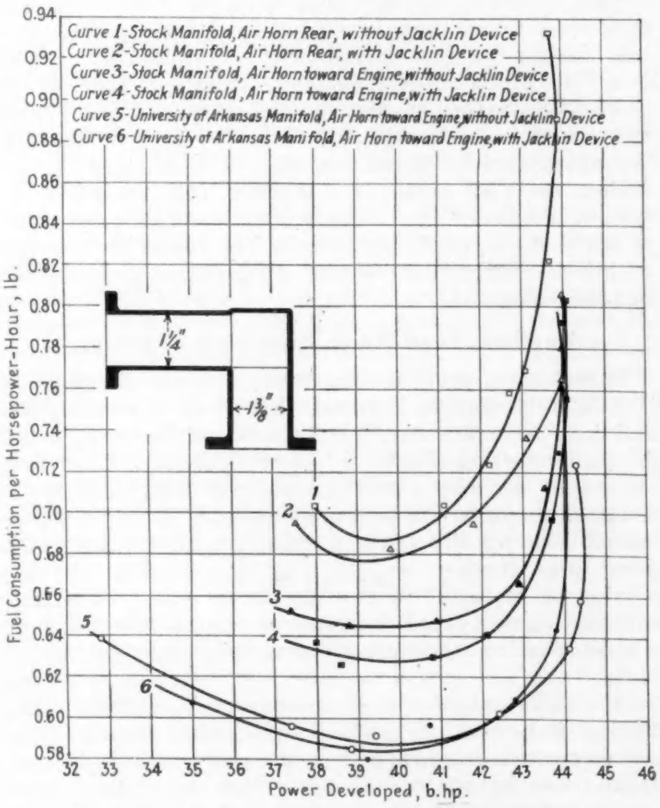


FIG. 24—CURVES OF SPECIFIC FUEL-CONSUMPTION PLOTTED AGAINST HORSEPOWER

These Results Were Obtained from Tests of a 3½ x 4½-In. Six-Cylinder Three-Port Engine at 1600 R.P.M. and Full Throttle. Data on the Type of Manifold Used, the Direction of the Air Horn and the Use of the Jacklin Device Are Given. Each Point on Any Given Curve Represents a Carbureter Needle-Valve Setting. The Small Insert Is a Transverse Section at the Carbureter Riser and Center Port of One of the Manifolds Used. This Manifold Is Made of 1/16-In. Sheet Metal and Has a Square Cross-Section Rather Than a Round One Because the Former Was Easier To Make. The End Branches Are 1⅜ In. Square and the Middle Branch Is 1¼ In., This Difference in Dimensions Being Accomplished by Dropping the Top Wall ⅛ In. and Bringing Each of the Sidewalls Inward 1/16 In. While the Bottom Remained on the Same Level as That of the End Branches. The Drop in the Top Wall Apparently Served as a Dam That Kept Some of the Rich Mixture from the Center Port

The power peaks of these curves are so flat that the values of fuel consumption at maximum power cannot be picked off accurately. If, however, we take a power value in each case just on the lean side of the maximum, say 43.5 hp., the corresponding fuel-consumption can be determined easily. This procedure shows improvements in economy as presented in Table 1.

Riser-Length and Air-Horn Effects

These results were obtained with manifolds having risers about 2 in. long from the carbureter to the branches. To test the effect of riser length, straight lengths of pipe 3, 6 and 9 in. long were inserted in turn above the carbureter. With the 9-in. riser, mixture-strength conditions were reversed, the rich mixture reaching the manifold on the side opposite the carbureter air-horn. With the 3-in. riser, the distribution was nearly equal at 1600 r.p.m. and full throttle. No serious consideration was given to increasing the riser length, however, as engineers rather generally agree that a long riser is to be avoided for good slow-speed work and easy starting.

To eliminate the effect of the carbureter air-horn, a carbureter was purchased which has no air-horn in the ordinary sense but a straight air-passage through the carbureter. The distribution at full throttle was improved, with a tendency to richness on the float-chamber side. This is presumably due to the disturbing effect of the tube that carries fuel from the float bowl to the main jet. At nearly closed throttle, the mixture is rich on the idling-jet side as before. Plugging up the idling jet allowed the angularity of the throttle disc to cause the mixture to be slightly over-rich on the opposite side.

In conclusion, I shall only echo Mr. Taub's statement that economy is the most important virtue to be gained by good distribution and is the factor most vitally affected by bad distribution. To aim at equal power-outputs from all cylinders is not enough, as a glance at a curve of power versus fuel-flow rate will show. Two cylinders on opposite sides of the power peak may be developing exactly the same power, yet one is running economically while the other is wasting all the extra fuel it receives.

TABLE 1—FUEL-ECONOMY IMPROVEMENTS WITH DIFFERENT CARBURETER-INLET DIRECTIONS AND THE JACKLIN DEVICE

Manifold	Stock				University of Arkansas	
Carbureter-Inlet Direction	Toward Rear		Toward Engine			
Jacklin Device Used	No	Yes	No	Yes	No	Yes
Maximum Power Developed, hp.	43.9	44.0	44.0	44.1	44.4	44.1
Specific Fuel-Consumption at 43.5 Hp., lb. per b.hp-hr.	0.808	0.743	0.701	0.684	0.619	0.628
Improvement Based on the Worst Conditions, per cent	0	8.1	13.2	15.3	24.6	22.3

Manifold Correction Better than Added Devices

MR. TAUB:—Professor Price points out a difference in method for determining weakness in distribution and offers for consideration the use of separators to catch the liquid fuel at each point of separation, the quantitative difference being the measure of quantitative distribution. His experience is similar to our own with this method, which is that only a portion, 50 per cent, of the fuel involved is collected and measured. We have felt that we should have knowledge of what happened to the other 50 per cent before distribution deductions can be made. For this reason we returned to finding the weak cylinder with lean mixtures, which after all is quick and relatively sure.

The data he presents of improvement in distribution by steps are interesting, particularly since he determined his progress graphically. However, his data support our contention that the major gain is to be made by normal correction and that devices such as the Jacklin device, which is apparently an extension of the riser above the T, are unreliable.

Professor Price indicates a leanest setting for maximum power for the original pipe of 0.89 lb. per b. hp-hr. fuel consumption for 43.8 hp., and with final correction without the Jacklin device, leanest setting for maximum power is 0.658 lb. per b. hp-hr. for 44.8 hp. Under this final set-up the Jacklin extension indicated a leanest setting for maximum power of 0.71 lb. per b. hp-hr. and 44 hp., an actual loss. This confirms our own experience with manifold extensions, which is that, with corrections made at the source of trouble in the manifold, carbureter or port, such devices as this extension are not needed. Professor Price bases his comparison upon a constant horsepower-output. We believe the comparisons based upon leanest setting for maximum power to be most informative. This represents the point where the weak cylinders are fully compensated for, and the consequent economy would indicate the over-richness necessary. Where the approach to the leanest setting for maximum power is gradual or fairly flat, obviously the minimum number of cylinders are being strengthened for power, while the maximum number of cylinders are being over-riched.

Problem as Viewed by a Carbureter Engineer

C. S. KEGERREIS[6]:—Mr. Taub has divided the problems into two major portions, (*a*) how to obtain satisfactory distribution and (*b*) measurement of its quality quantitatively. The carbureter engineer has little to do with the type or details in the design of most induction systems. He is usually called upon to adapt the carbureter to whatever conditions the particular four, six or eight-cylinder engine has integrally built into it. Consequently, the carbureter engineer's task is to consider (*a*) very seriously. His methods under (*b*) must be quick and point the way generally to determine the troubles. The magnitude of the measurements very seldom interest this individual but he will usually have the troubles resolved into engine design, ignition or carburetion. The last term includes not only carbureters but also the induction system, up to and including valves and the hot-spot application. In fact, as more information becomes available, the exhaust system shows a part oftentimes neglected. To find an engine designer making a statement such as Mr. Taub has, regarding cooperation on definite basis, that is, to state the manifold troubles before the carbureter man finds them, really is encouraging. Sometimes the carbureter-specification engineer is compelled to change his carbureter characteristics completely, in fact, warping them so badly that we often wonder if the result is a fully developed and real carbureter. This cooperation, of which Mr. Taub speaks, brings joy to the carbureter man and allows him to speak frankly in recommending changes in the remainder of the carburetion system built into the engine castings.

Under the heading of quality, the author lists nine different factors. I believe that our problem might seem more simple if these factors were redivided. Under degree of atomization, the lack of homogenity might well be placed, since the basic purpose in atomization is to overcome lack of homogeneity, whether it be effected in the carbureter, the manifold or both. This is a progressive problem that should start in the carbureter and be improved upon as the flow progresses toward the combustion-chamber.

The factors of precipitation, division of wet ends and port design could well become subservient to the manifold design for fuel distribution. Application of heat is a very broad subject and is at least as important in procuring quality of distribution as any other factor mentioned. The reason for this statement is that, if the other factors listed are not well balanced in the design, the heat application must remedy the other resultant shortcomings. The remaining factor, division of air-flow, is relatively simple but must be grouped with heat application and fuel distribution as the three factors concerned.

Engines Need Good Breathing Capacity

In making a previous statement that air distribution is relatively simple, I meant that it is more tangible and data can more readily be placed, perhaps, upon the dynamometer log sheet. I like to think of a throttling engine as basically a self-operated air-pump. If it be designed as such, the passageways and valves certainly cannot restrict the induced volume. If we carry the pump idea further, we are also interested in the expulsion of material on the discharge side. It is universally agreed that horsepower is merely mixture weight passing through the engine, hence the pump idea.

If certain troubles are encountered in inducing the fuel, if it be wet, to reach its predestined point, then the compromise between capacity and velocity, if necessary, can be effected at the proper point and cause less interference in upsetting the other design factors of the engine. A practical example that the carbureter man encounters somewhat frequently is as follows: the engine man desires torque and horsepower and he wants more of it per unit piston displacement than heretofore. To choose a practical example in a six-cylinder engine where valves were a restriction, opening the intake ports and air-flowing them separately resulted in only 2.3 per cent increase in volume. Increasing manifold size before enlarging ports resulted in a 10-per cent increase and, after opening both, a flow of 11 per cent was effected. Procuring the maximum volume in this manner, the valves were increased, with a resultant increase over the original engine of 16.2 per cent. The air distribution to each port was made reasonably correct to give a well-balanced and maximum-volume breathing-ca-

[6] M.S.A.E.—Chief engineer, Tillotson Mfg. Co., Toledo.

pacity. In an eight-cylinder engine, the valves were sufficiently large but the intake manifold decreased the flow 9 per cent. This restriction, however, was uniform to all ports and consequently the air distribution was satisfactory.

In dealing with some engines the exhaust manifold. including the exhaust pipe, has considerable effect on air-flow and also on each cylinder, its magnitude depending upon the ejector effect in the manifold and the resultant scavenging. A certain engine has shown a 4-per cent increase in flow when using the exhaust over that when removed.

Under the heading of air-distribution, the arrangement of manifold pipes in different engines with various numbers of cylinders should be considered. This is particularly true in the four and straight-eight designs. It can only be mentioned here because a detailed discussion would necessitate a complete paper.

Mr. Taub makes this statement:

> An excellent practice would be to have a valve timing to give a high-speed range in excess of that desired and then limit the top range to the point required by decreasing the manifold area.

What an ideal situation from a carburetion viewpoint! Too often manifolds and carbureters are opened in an attempt to procure better power and torque at mid-speed range. For example, three runs were made on an engine with restricted valves; first, the standard engine; then with opened manifold and carbureter; and again with enlarged valves. The comparison leaves no doubt as to the results. Opening the carbureter and manifold showed a slight effect but, if anything, decreased atomization and upset liquid distribution in the manifold. Enlargement of the valves gave the required increase so that the manifold was returned to its original size. Yet the carbureter man, both before and after production starts, is constantly being called upon to remedy similar situations. This point is raised in the hope that the modern engine may be well designed and carbureted, with all factors interbalanced so that the final analysis results in smooth and snappy performance.

Fuel Distribution

If air distribution is satisfactory and the volume displaced by the engine a maximum, we may surmise from our previously accepted standards that fuel distribution is in danger. I believe, and have stated, that the resulting manifold-design is more flexible, and, if correcting certain puddling or inadequate atomization is necessary, the manifold has sufficient tolerance to incorporate satisfactorily improved fuel distribution.

Mr. Taub states that the fuel must not only be uniformly distributed to each cylinder but also homogeneously mixed with its air in that cylinder. So, if the atomization is not accomplished properly in the carbureter, the manifold must aid in some manner. Hence every change in direction of the fuel or wet mixture offers opportunity for another effort at improvement in mixing. Sharp corners on the inside of bends and intersections are stressed by the author and rightly so. In my opinion the outside radius is not so important. Rebound sections may aid materially and the mixing by reatomization at any change in direction of airstream really helps the cause along. I believe that the sharp corners are particularly necessary at the intersection of the riser and the lateral. Manifolds with other factors similar except larger radii placed at the riser intersection have been compared, with the result that detonation and consequent poorer distribution were present. A well-balanced manifold with sharp corners is usually smoother in operation, causes less detonation at low speeds and requires less time in adjusting carbureter specifications.

Heat Application

The extent of heat application is dependent upon the atmospheric or resultant hood temperature, as well as upon the atomization of the fuel. The exact position of the heated area is of such consequence that the vaporizing must be done before the first division of the mixture, with the fuel properly heated for vaporization and the minimum heating of the airstream. Usually the atomization from most carbureters is best in the center of the mixture stream. By noting different carbureters and various throttle-positions with glass tubes as manifolds, we find that the stream is somewhat deflected and in many cases an appreciable spiralling and resulting centrifugal action on the fuel is started at the throttle disc. This effect is evidenced by a heavier liquid-film on the walls with the more-subdivided particles flowing somewhat near the center. Thus a small but very effective vaporizing surface is desired at the manifold entrance.

To obtain efficient warming and the minimum heat-lag or gradient, a riser wall of minimum practical thickness is recommended. This construction aids in two ways; first, the minimum warming-up period and, second, an efficient design can be evolved for maximum fuel-vaporization with the minimum heating of the manifold flange, with the result of reducing heat conduction to the carbureter at the higher atmospheric temperatures. If, in the design of any heat box, proper temperatures and vaporization of the fuel have not been effected, then rebound spots may be located at the T. If the fuel, in leaving the rebounding areas, can be deflected for vaporization before passing the manifold division point, then the result is extremely pleasing.

Only updraft design has been considered thus far. Where the down spout is used instead of the riser, this discussion cannot apply, because the heat and atomization situation is entirely reversed. Some heat on the riser is desirable but the enshrouding of the T must be studied in detail. Atomization becomes more of a problem in downdraft carburetion than it ever has occupied with the reverse position. This is particularly true at low engine-speeds. Unless the fuel is atomized, the engine torque drops rapidly.

Mr. Taub brings up the question of preheated air versus the hot-spot method. We all appreciate that using heated air on the carbureter intake is inadvisable from the power viewpoint and consistent carbureter functioning. However, the use of the sensible heat in the incoming air starts vaporization immediately at the nozzle outlet and aids materially even before the mixture has passed the throttle shutter. In fact, it really uses efficiently the atomization started in the carbureter. Consequently, by the time the mixture stream has reached the dividing point of the manifold T, the vaporization and mixing are so thorough that almost any design of manifold will suffice. Smooth-acceleration problems, as far as the manifold is concerned, are not then so great. These results have been derived from innumerable tests in the laboratory and on the road. In fact, leaner mix-

tures can be used with consequently good economy. However, I do not recommend such a set-up, as these statements are included only to illustrate that atomization and consequent vaporization must be effected immediately and not after any mixture-division point is passed.

Number of Ports for Best Distribution

A carburetion survey of the industry indicates that some organizations have carbureted nearly equal numbers of two, three and four-port induction systems on the six-cylinder eniine. Investigating these data in detail, we find that both cross and straight-flange carbureters are used on all three designs. The power outputs of these various engines per unit piston displacement are somewhat close, as are the fuel consumptions. Each engine is idled to about the same speed and the maximum power is developed at about the same maximum speed. Can we state definitely that any one porting is really superior to the other two? The carbureter man has encountered troubles, called distribution or atomization if you wish, in each of the three types. Also, individual engineers in the same organization state that each preferred a different type. Consequently, to set down the advantage and disadvantage of each design logically and intelligently is an impossibility with our present knowledge.

As we gain experience in the designing of manifolds, engineers have been known to change from perhaps two to three ports or from four to three ports and conversely with the accomplishment of a demand, that is, higher power per unit displacement, or improvements in economy as designated by Mr. Taub's fishhooks. I believe investigators have found manifolds of each of the three types with the end cylinders running rich and the center cylinders lean, or conversely. Finally, if the production date is not too close at hand, the distribution is usually well equalized, the carbureter man overcomes his individual troubles, and behold, the job supposedly is satisfactory.

Is not the gist of all this discussion self-contained in the three factors outlined: first, a well-balanced air-distribution; second, an effective fuel-distributing design; and, third, some final assistance rendered to the mixture by proper heat application for fuel vaporization?

Cannot some means be provided to continue this compilation of data on mixture distribution? As Mr. Taub states, codifying the present material will aid. However, we must continue all efforts until the problems are completely solved and the data made available to the engineer designer on the drawing-board.

MR. TAUB:—Mr. Kegerreis' discussion is in the nature of a review of my paper and I am gratified to note that in the main he concurs. Such a discussion and review of a designer's remarks by the carbureter man is certainly constructive. Since the objective of the original paper was to promote a more general discussion of the distribution problem, Mr. Kegerreis' reaction as indicated in his contribution is wholesome.

FRANK N. NUTT[7]:—Will Mr. Taub explain the effect of distribution on spark-plug performance in cold starting?

MR. TAUB:—Bad cold-distribution is very often the underlying fault in complaints against spark-plugs for cold starting. If a condition of overrunning ports prevails, such as exists in a four-port single-lateral manifold, the heavy wet fuel can separate at the intermediate port, flooding cylinders Nos. 1 and 2 and also Nos. 5 and 6. Since the light ends usually follow the airstream, the mixture that finds its way to the end cylinders is of the minimum volatility. This situation is indicated, as a rule, by the four wet spark-plugs in the end cylinders and the two dry spark-plugs in the center cylinders.

Indicator Diagrams Seen as an Aid

H. M. JACKLIN[8]:—Mr. Taub has mentioned only two methods for measuring the quality of distribution—exhaust-gas analysis and the spectroscope—aside from the excellent method he later presents in some detail. He attributes these methods more or less erroneously to the physicist and dismisses them as methods or tools for indicating where and how to improve distribution. However valuable these methods may be, another method is available for arriving at results that are apparently more definite and, if anything, easier of application. I refer to the use of an indicator as recently outlined in the S.A.E. JOURNAL[9]. These data were obtained subsequently to the last Semi-Annual Meeting. The method lends itself to use in an ordinary laboratory by the laboratory operator. The calculations are not at all complicated nor do they take much time.

Further, the use of lower-loop diagrams such as those shown in Figs. 7 and 9 of my 1929 Semi-Annual Meeting paper[10] gives an excellent method of measuring the relative filling of the several cylinders under actual operating conditions. In addition, arrangements can easily be made to obtain cylinder and manifold diagrams simultaneously from all cylinders and various points on a manifold.

Professor Price's work has been very interesting to me in that he has obtained dynamometer results on the manifold extension that I had been able to use only on the road. This extension is shown in Fig. 5 of my paper[11] and the indicator diagrams obtained while using it are shown in Fig. 6,

These and other results from the use of an indicator have convinced me that an indicator is a very valuable tool that is not yet fully appreciated in everyday routine testing. The composite type of card from the improved indicators that we now have are representative of mean cylinder conditions. Diagrams from such improved indicators are reproduced as Fig. 12 of my paper[12], wherein anyone can see their possibilities in analysis as well as the evident improvement in the diagrams themselves.

I believe that the diagrams will locate the variations among the cylinders very definitely. Their use along with Mr. Taub's excellent method should develop very rapid and accurate results of great general benefit.

I have one further suggestion to make. Since we are all attacking a problem having a considerable diversity of factors, why would it not be a good idea for the Research Committee of the Society to father a project in some neutral well-equipped laboratory where all the various factors can be evaluated by one or more methods to the end that (*a*) a definite and accurate method of

(*Concluded on p.* 484)

[7] M.S.A.E.—New-devices research engineer, A.C. Spark Plug Co., Flint, Mich.

[8] M.S.A.E.—Associate professor of automotive engineering, Purdue University, West Lafayette, Ind.

[9] See S.A.E. JOURNAL, November, 1929, p. 530.

[10] See S.A.E. JOURNAL, November, 1929, pp. 527 and 528.

[11] See S.A.E. JOURNAL, November, 1929, p. 527.

[12] See S.A.E. JOURNAL, November, 1929, p. 531.

Effect of Design on Engine Acceleration[1]

By D. B. Brooks[2] and C. S. Bruce[3]

Annual Meeting Paper — *Illustrated with* Charts, Drawings and Photographs

THIS REPORT covers tests made at the laboratory of several automobile companies to ascertain the effect of engine design and of different fuels on the acceleration characteristics of a number of different engines.

The work was authorized by the Cooperative Fuel Research Steering Committee as an extension of the program of fuel research because the tests on fuel volatility and engine acceleration made by the Bureau of Standards were all made on one engine.

The present report describes the types of manifold and manifold jacketing used on the six and eight-cylinder engines and the conditions under which tests were made with three fuels supplied by the Bureau. Results of uniform acceleration tests on seven engines are given and discussed. Two facts that are said to appear with reasonable consistency are that the curves of relative effectiveness of the three fuels for producing acceleration tend to cross at the lower temperatures and the blend of equal parts of Domestic Aviation gasoline and U. S. Motor gasoline produces roughly one-half more improvement in acceleration than does Aviation gasoline over U. S. Motor fuel.

Typical curves showing the effect on acceleration of updraft and downdraft manifolds, manifold shape, manifold heat and accelerating devices are presented and discussed. An empirical rule is given for finding the relative effectiveness of fuels for acceleration at any given manifold temperature.

Considering design factors, it is pointed out that, for both updraft and downdraft manifolds, the acceleration is in the order of the fuel volatilities up to 500 r.p.m., and from there up to 1,000 r.p.m. is in the reverse order, due to over-richness.

The increase in acceleration that results from accelerating charges and from supplying heat to the manifold is shown by curves and discussed. These show that the heat and accelerating charge improve the acceleration up to about 500 r.p.m. but that reversal occurs at higher speeds. The conclusion is drawn that, at factory setting of the carbureter for maximum power, the addition of heat, accelerating charges and increase in volatility of the fuel all serve to increase the acceleration at engine speeds below about 700 r.p.m. but to decrease the acceleration at higher speeds.

IN A PAPER[4] presented at the 1929 Annual Meeting the results of two series of tests made on three special fuels having widely different A.S.T.M. 50-per cent points were discussed and attention was called to a relation between curves of relative volatility and curves of relative effectiveness for acceleration for a series of four fuels over a temperature range from —10 to +90 deg. cent. (14 to 194 deg. fahr.) These tests were made in the dynamometer laboratory of the Bureau of Standards, where the factors affecting acceleration were carefully controlled.

Since these and all previous tests were made on one engine, the Cooperative Fuel Research Steering Committee authorized an extension of the program to ascertain the effect of engine design and of different fuels on the acceleration characteristics of a number of engines. Steering Committee representatives of several automobile companies obtained permission for Bureau representatives to conduct engine tests at their respective laboratories. Without the cordial cooperation of these companies, the tests herein reported would have been impossible. In all, about 560 acceleration tests were run on a total of nine engines at the laboratories of four automobile companies and the Bureau of Standards.

Acceleration was measured by means of the portable spark-accelerometer exhibited and described at the 1929 Summer Meeting. This apparatus is again described in Appendix 1.

As this work was done at a number of laboratories and in a very limited time, test installations could not be made identical. However, the inertia load imposed on each engine was known and in general was approximately equal to that imposed on it by the car for which it was designed.

Test Procedure

Uniform acceleration tests made on seven engines with each of three fuels at each of three manifold temperatures in the range from 80 to 200 deg. fahr. comprised the volatility runs. The three fuels, supplied by the Bureau of Standards, consisted of a Domestic Aviation gasoline, a U. S. Motor gasoline, and a blend consisting of equal parts of the two. The A.S.T.M. distillation curves of these fuels are shown in Fig. 1. The volatility tests were made at carbureter settings giving known mixture-ratios equal for the three fuels and just sufficiently rich to ensure consistent acceleration with U. S. Motor gasoline.

The manifolds used on the test engines were jacketed as shown in Fig. 2 to enable close regulation of temperature for the volatility tests. This manifold jacketing in each case covered at least part of the riser, but in other details these jackets were quite diverse. Attention is called especially to this fact, as it is believed to be the major cause of diversity in the results of the volatility runs.

To study the combined effect of induction-system and engine design, acceleration runs were made on each engine at factory carbureter-setting, with and without accelerating device and with and without manifold heat. The regular commercial gasoline available at the

[1] Publication approved by the Director of the Bureau of Standards of the United States Department of Commerce, City of Washington.

[2] S.M.S.A.E.—Automotive engineer, Bureau of Standards, City of Washington.

[3] S.M.S.A.E.—Assistant mechanical engineer, Bureau of Standards, City of Washington.

[4] See S.A.E. Journal, June, 1929, p. 609.

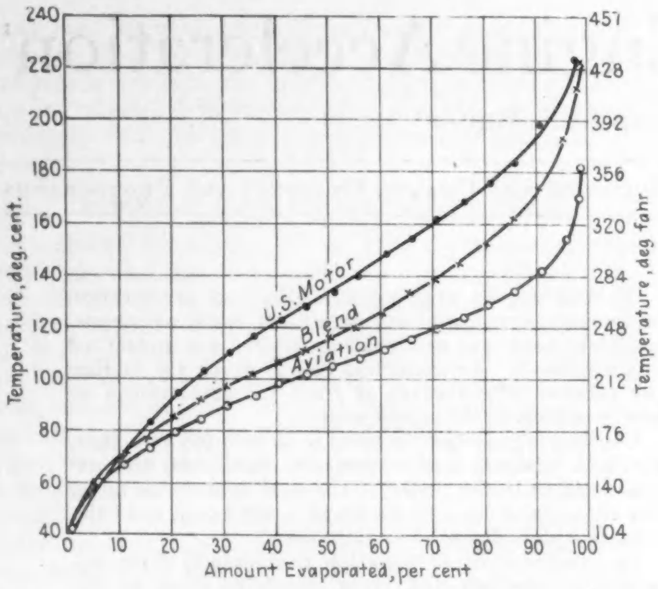


FIG. 1—DISTILLATION CURVES OF TEST FUELS USED IN ACCELERATION TESTS

factory was used for most of these runs, the three special fuels mentioned being used for comparison in a few runs. Three of the engines were run twice using a different manifold in each case. Runs were also made on each engine with different combinations of carbureter and manifold, firing separately various groups of cylinders, in order to study distribution.

Results

The results of the volatility runs are presented in the same manner as at the 1929 Annual Meeting. The measure of relative fuel volatility, found to give curves similar to those derived from acceleration tests, is obtained as follows: One fuel is selected as the reference. Its volatility is taken as a unity at all temperatures. At 5 per cent evaporated, the A.S.T.M. temperature, in degrees absolute, for the reference fuel is divided by that for one of the other fuels, say Fuel *A*. The value so obtained is called the relative volatility of Fuel *A* with respect to the reference fuel. In a similar way, the relative volatility is found for each of the other fuels at 5 per cent evaporated. This procedure is then repeated for each fuel at successively higher percentages evaporated. By plotting the values so obtained at each percentage evaporated against the A.S.T.M. temperature of the reference fuel at the same per cent evaporated, curves of relative volatility such as are shown in Fig. 3 were obtained. It is emphasized that these curves are derived solely from the A. S. T. M. distillation data for the fuels.

The curves of relative effectiveness of these fuels for producing acceleration, shown in Fig. 4, are, on the contrary, derived solely from engine-acceleration test data for the same fuels and do not involve A.S.T.M. data in any way. The effectiveness of a fuel for producing acceleration is defined as the air-fuel ratio supplied by the carbureter divided by the effective air-fuel ratio entering the cylinders at the same instant. As described more fully in a previous report[4], the effective air-fuel ratio is found by comparing the observed acceleration, at a speed 50 r.p.m. above the initial speed, with a contour chart derived from brake-torque versus mixture-ratio tests at various constant speeds. Since acceleration at any instant is proportional to available brake torque, the effective air-fuel ratio found is that mixture which, if vaporized and distributed as under constant-speed operating conditions, would give brake torque sufficient to produce the observed acceleration. To minimize the effect of differences in supplied air-fuel ratio, speed, and so forth, results are expressed as effectiveness of the fuel relative to one fuel chosen as a reference, in the same manner as the relative volatilities.

That a degree of similarity exists between these two sets of curves is obvious in the case of fuels *D*, *E* and *F*.

The low point on the curve for Aviation gasoline near 280 deg. cent. absolute at first was thought to be an insuperable obstacle to correlation. It is now believed that the explanation of this anomaly lies in the fact that these tests were run with the manifold cold but the jacket maintained at 80 deg. cent. (176 deg. fahr.). Tests made with U. S. Motor, Aviation and the blended gasolines at a similarly low manifold-temperature, both with jacket at the same temperature as the manifold and with the jacket at 80 deg. cent., indicate that the low value of acceleration obtained with Aviation as mentioned is indeed due to this abnormal condition, which is one that is rarely met in practice. In order, therefore, that the relation found may apply, it is necessary that the manifold temperature be not substantially lower than that of the water-jacket[5].

[5] For more complete explanation see S.A.E. JOURNAL, August, 1929, p. 132.

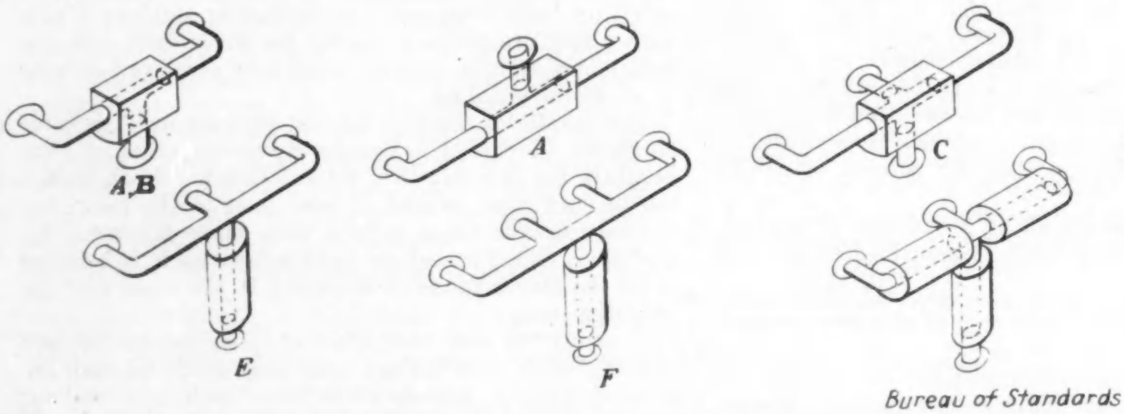


FIG. 2—TYPES OF MANIFOLD AND MANIFOLD JACKETING OF TEST ENGINES

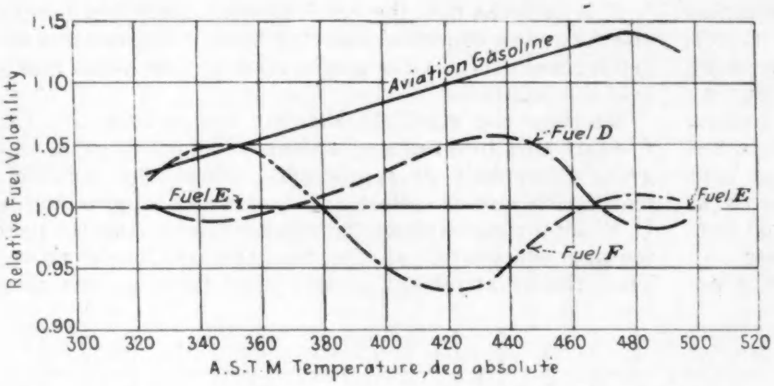


FIG. 3—RELATIVE VOLATILITY OF AVIATION GASOLINE AND FUELS *D*, *E* AND *F*

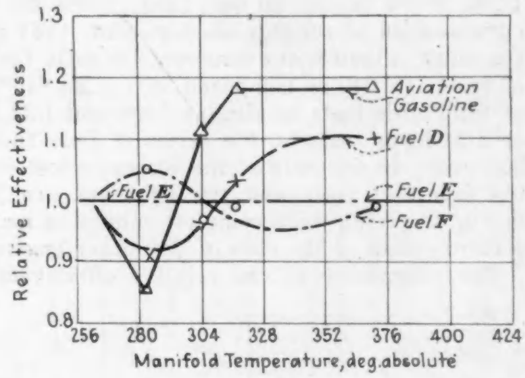


FIG. 4—RELATIVE EFFECTIVENESS OF THE FOUR FUELS FOR PRODUCING ACCELERATION

The fact that points occur on the curves in Fig. 3 at absolute temperatures which are a constant (about 1.2) times the absolute temperatures at corresponding points on the curves in Fig. 4 is considered further evidence of a relationship between distillation and acceleration data.

To test this apparent relationship, acceleration runs were made on three fuels having distillation curves quite similar to but not identical with those shown in Fig. 1. The distillation curves of these fuels crossed at 158 deg. fahr. (70 deg. cent.). From this and the constant factor derived from Figs. 3 and 4, it was computed that these fuels should give equal accelerations at 350 to 400 r.p.m. at 48 deg. fahr. (9 deg. cent.). Fig. 5 shows the observed accelerations obtained at that temperature to be equal within the limits of experimental error. From the complete series of runs on these fuels, it was found that a manifold temperature of 11 deg. cent. (51.8 deg. fahr.) corresponded to a fuel-distillation temperature of 69 deg. cent. (156.2 deg. fahr.), giving a factor of 1.20.

Using this temperature factor, Fig. 6 was plotted from the A.S.T.M. data (see Fig. 1) of the three fuels used in the acceleration test work at the various laboratories. From this curve it is seen that the relative effectiveness of these fuels for acceleration should be equal between 40 and 50 deg. fahr. if the relation and temperature factor used are correct.

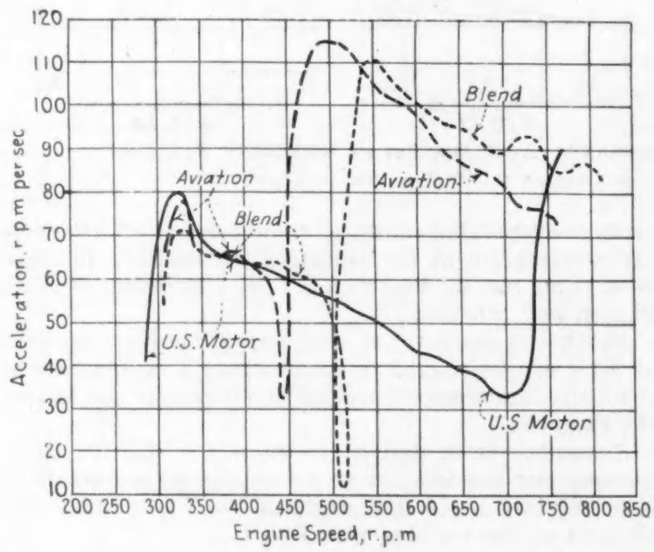


FIG. 5—ACCELERATION OBTAINED WITH AVIATION, U. S. MOTOR AND BLENDED GASOLINES AT AN OPERATING TEMPERATURE OF 9 DEG. CENT. (48 DEG. FAHR.)

Figs. 7 and 8 show the results obtained from tests made on Engine *A*, plotted as relative effectiveness for acceleration. The results shown in Fig. 7 were obtained with an updraft manifold; those in Fig. 8 with a downdraft manifold. Figs. 9 to 13 show the curves of relative effectiveness for acceleration for these same fuels, as found on Engines *B*, *C*, *D*, *E* and *F*. Fig. 14 shows the corresponding curves as found on the engine used at the Bureau of Standards.

Typical curves illustrating the effect on acceleration of manifold shape, manifold heat and accelerating devices are presented in Figs. 15 to 21. These will be discussed later herein.

Discussion of Results

Fuel Volatility.—While the curves shown in Figs. 7 to 13 are quite different in detail, as might be expected from the diversity of design, manifold jacketing, air-fuel ratio, location of manifold-jacket thermometer and so forth employed, yet in the aggregate two facts appear with reasonable consistency; the curves for the three fuels tend to cross at the lower temperatures, and the improvement of the blend over U. S. Motor gasoline is roughly one-half that of Aviation gasoline over U. S. Motor fuel.

From these curves, the average value of the temperature at which Aviation gasoline is just equal to U. S. Motor is 60 deg. fahr.; that at which the blend equals

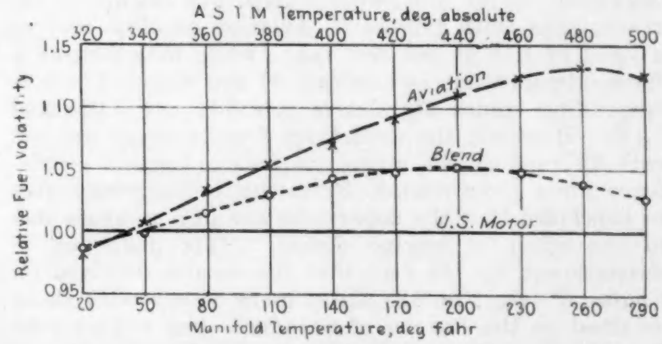
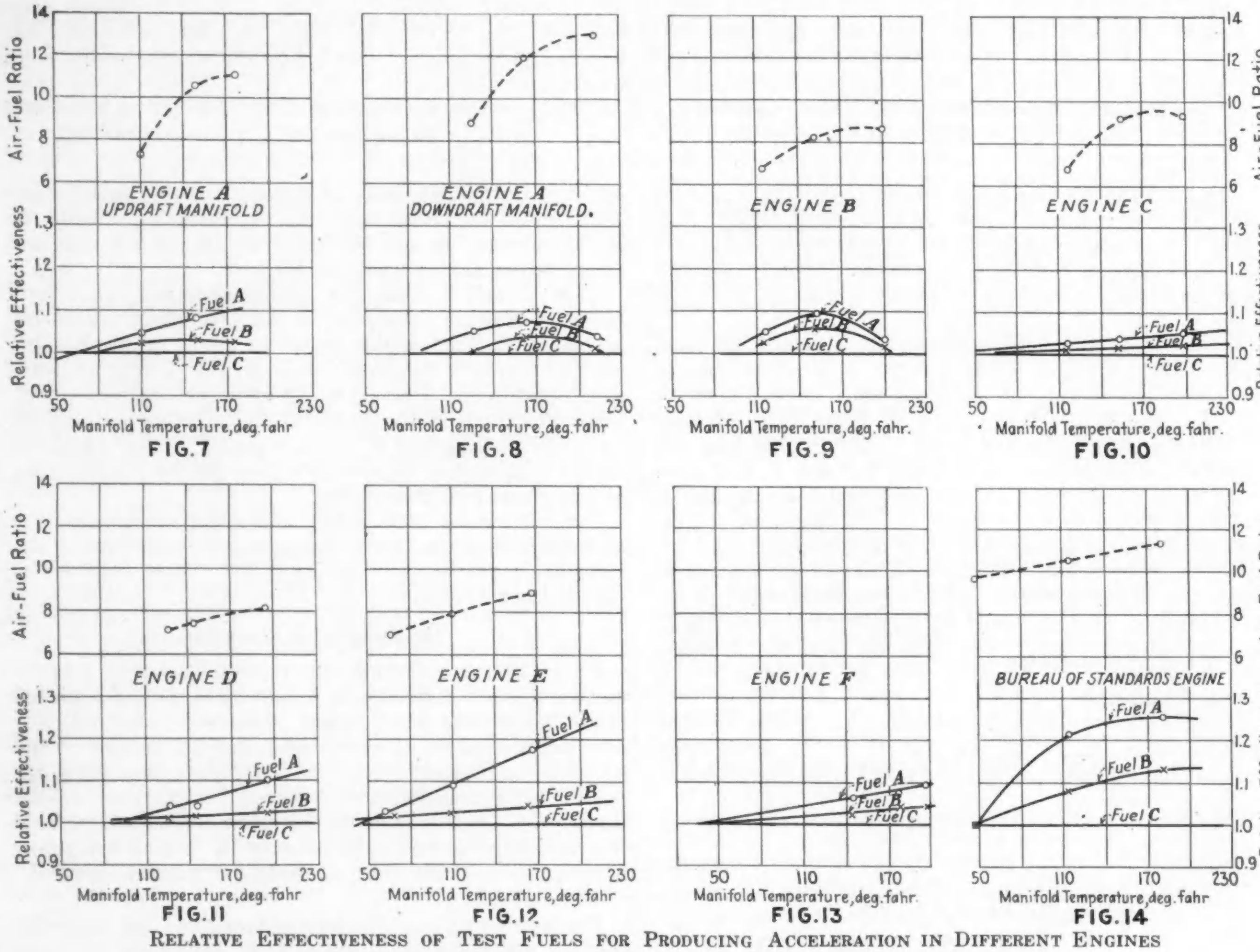


FIG. 6—RELATIVE VOLATILITY OF TEST FUELS USED IN ACCELERATION TESTS

U. S. Motor is also 60 deg. fahr. Since the distillation curves cross at roughly 66 deg. cent. (151 deg. fahr.), the mean value for the temperature ratio for this series of tests is 1.18, as compared with 1.20 for the Bureau of Standards tests on similar fuels and 1.22 for Bureau of Standards tests on the series of four fuels reported last year. In the case of the Bureau's test engine, both the manifold riser and the branches are jacketed as in Fig. 2, giving more complete control of manifold temperature than in the case of any other engine used.

The magnitude of the relative effectiveness for acceleration varies considerably from one engine to another; thus, with Engine *E*, Aviation gasoline reaches a value of 1.18 at 165 deg. fahr., while with Engine *C* its maximum value is 1.055 at 197 deg. fahr. The corresponding values of relative volatility are 1.085 and 1.115. However, the departures from average are not entirely random but appear to have a certain consistency for a given engine. From this it may reasonably be concluded that the departures are in a measure due to the effect of engine design. This deduction is strengthened by the fact that the results obtained on Engine *E* (see Fig. 12) agree more closely with those obtained on the Bureau of Standards test engine (see Fig. 14) than do those of any other engine. The design of Engine *E* is very similar to that of the Bureau's engine.



RELATIVE EFFECTIVENESS OF TEST FUELS FOR PRODUCING ACCELERATION IN DIFFERENT ENGINES

Broken-Line Curves Show the Air-Fuel Ratios Used at the Various Temperatures

It is believed that the results herein described justify the following empirical rule for finding the relative effectiveness of fuels for acceleration at any given manifold temperature:

Multiply the manifold absolute temperature by 1.2. Convert this into units of ordinary temperature, as degrees fahrenheit or centigrade. From the A.S.T.M. distillation curves, select one fuel which approximates U. S. Motor gasoline as the reference and note its percentage evaporated at the temperature found above. Then the arrangement of the other fuels at this percentage evaporated indicates their relative effectiveness for acceleration at the manifold temperature in question, those having higher A.S.T.M. temperatures being poorer, and conversely.

Further, a quantitative relationship between any pair of fuels can be roughly ascertained by a comparison of their absolute temperatures as illustrated by the following example.

Example.—It is desired to know the relative effectiveness for acceleration in an engine whose manifold is maintained at 50 deg. cent., of the fuels whose distillation curves are shown in Fig. 1.

50 deg. cent. = 323 deg. cent. absolute

$1.2 \times 323 = 387.6 = 114.6$ deg. cent.

The distillation temperature at which comparison

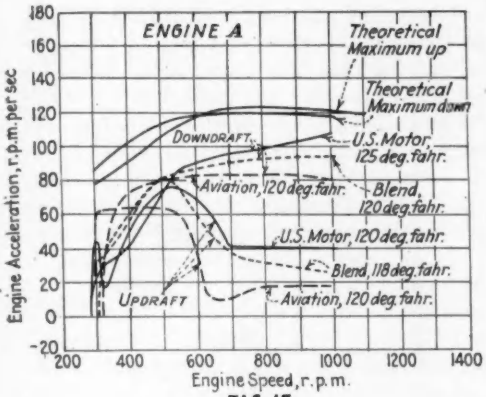


FIG. 15

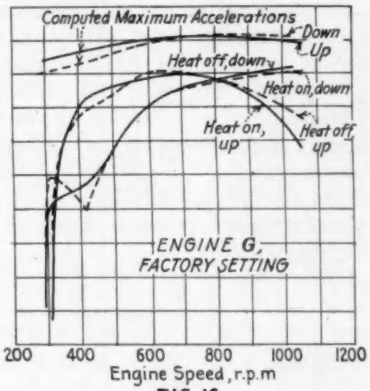


FIG. 16

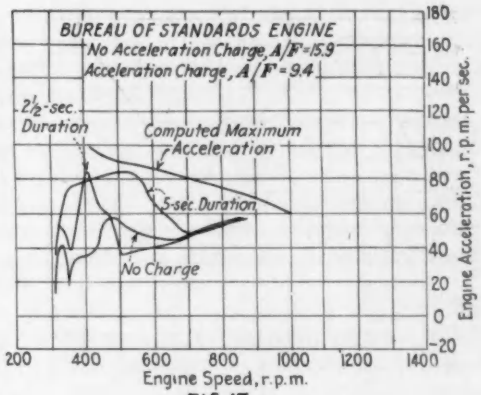


FIG. 17

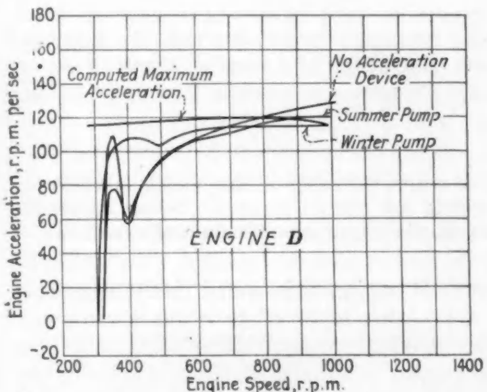


FIG. 18

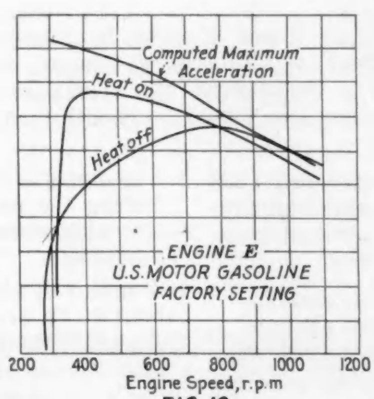


FIG. 19

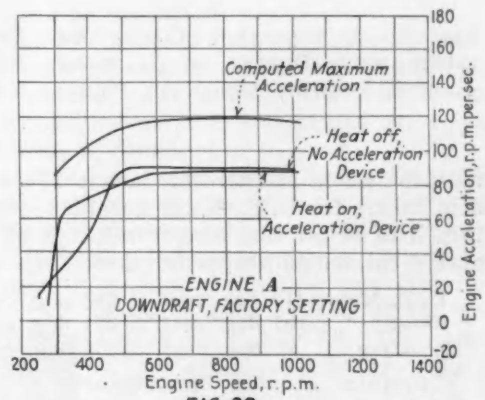


FIG. 20

ACCELERATION CURVES OBTAINED WITH DIFFERENT ENGINES USING UPDRAFT AND DOWNDRAFT MANIFOLDS. COMPUTED MAXIMUM-ACCELERATION CURVES ALSO SHOWN

Fig. 15—From Engine *A*, Using Updraft and Downdraft Manifolds and Run on U. S. Motor, Aviation and Blended Gasolines

Fig. 16—From Engine *G*, Using Updraft and Downdraft Manifolds; Factory Carbureter-Setting, Heat on and Heat off

Fig. 17—Curves Showing Effect of Duration of Accelerating Charge. Obtained with Bureau of Standards Engine

Fig. 18—Curves Showing Effect of Duration of Accelerating Charge, Using Factory Setting for Gasoline and Carbureter

Fig. 19—Curves from Engine *E* Showing Effect of Heat on the Manifold, Using Factory Setting for Gasoline and Carbureter

Fig. 20—Curves from Engine *A* Showing Effect Produced by Using Heat and an Accelerating Device, Using Downdraft Manifold and Factory Setting for Gasoline and Carbureter

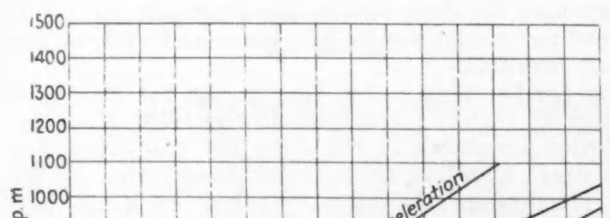


FIG. 21—SPEED-VERSUS-TIME CURVES OBTAINED WITH ENGINE *G*, USING UPDRAFT AND DOWNDRAFT MANIFOLDS AND FACTORY GASOLINE AND CARBURETER SETTING

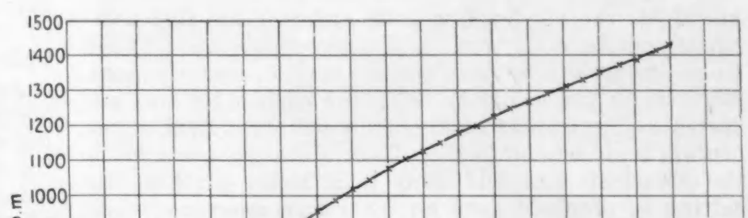
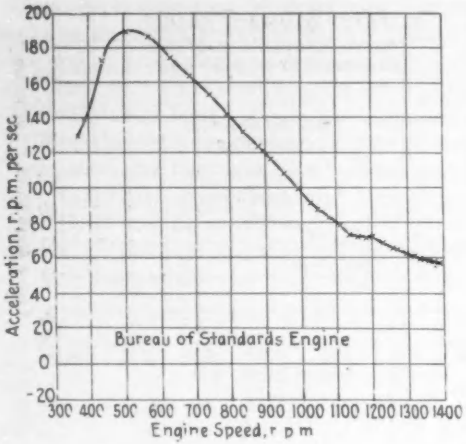
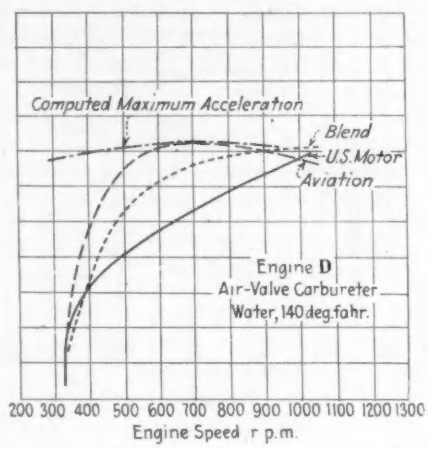


FIG. 22—SPEED-VERSUS-TIME CURVES FROM BUREAU OF STANDARDS ENGINE, SHOWING AGREEMENT OF POINTS





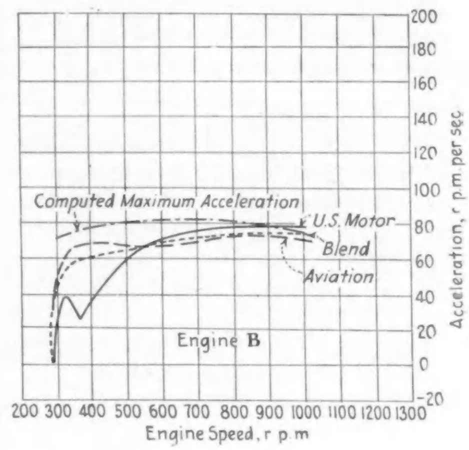


FIG. 23—ACCELERATION CURVES OBTAINED WITH BUREAU OF STANDARDS ENGINE, SHOWING INDIVIDUAL POINTS

FIG. 24—FROM ENGINE *D*, SHOWING EFFECT OF VOLATILITY, USING AIR-VALVE CARBURETER, NO ACCELERATING DEVICE AND THREE DIFFERENT FUELS

FIG. 25—FROM ENGINE *B*, SHOWING EFFECT OF VOLATILITY, USING FACTORY SETTING AND THREE DIFFERENT FUELS

must be made is therefore about 115 deg. cent. (239 deg. fahr.) for U. S. Motor gasoline. At this temperature it is 34 per cent evaporated. At 34 per cent evaporated the temperatures for these fuels are

U. S. Motor	115 deg. cent. = 388 deg. cent. absolute
Blend	101 deg. cent. = 374 deg. cent. absolute
Aviation	92 deg. cent. = 365 deg. cent. absolute

Therefore, at this temperature, Aviation gasoline will give the best and U. S. Motor fuel the poorest acceleration of the three fuels. Roughly, the actual relative effectiveness will be

U. S. Motor	388 ÷ 388 = 100 per cent
Blend	388 ÷ 374 = 104 per cent
Aviation	388 ÷ 365 = 106 per cent

Design Factors

A set of curves on Engine *A* are shown in Fig. 15, for updraft and downdraft manifolds, water-jacket temperature about 120 deg. fahr. and no accelerating device. It is seen that for both updraft and downdraft manifolds the acceleration is in order of the fuel volatilities up to 500 r.p.m. and from there up to 1000 r.p.m. is in the reverse order, due to over-richness. Here, as in the volatility tests, the carbureter was adjusted to the leanest setting at which consistent acceleration could be obtained on U. S. Motor gasoline. With the downdraft manifold using U. S. Motor gasoline, the setting so obtained gave an 8.8:1 mixture-ratio, while with the updraft manifold a mixture of 7.5:1 was required.

It will be noted that in Fig. 15 the acceleration on U. S. Motor gasoline did not begin to increase markedly until the engine reached a speed of 350 r.p.m. The following explanation of this behavior was offered in a previous paper[6].

> While the engine is idling, the inlet manifold is under reduced pressure; hence vaporization is good and the walls are relatively dry. If the engine speed is low when the throttle is opened, as in this case, the low air-speed in the inlet manifold allows formation of comparatively large droplets of gasoline in the spray from the main jet, and considerable liquid is deposited on the walls, forming a film which is blown along the manifold by the airstream. Some of the droplets remain in the vapor-air stream and reach the cylinders.

At speeds of about 500 r.p.m. (air-speed in the manifold about 40 ft. per sec.), this layer of gasoline is swept up into the cylinders, causing the mixture to become too rich, thereby decreasing the acceleration. Finally, at speeds of about 800 r.p.m. (velocity in the manifold about 70 ft. per sec.) the walls have given up most of the liquid and the engine received only the mixture ratio supplied by the jet.

The curves for the downdraft manifold represent approximately the same water-jacket temperature as those for the updraft manifold, but the supplied mixture-ratio was considerably leaner in the latter case. The same effect is seen; that is, Aviation gasoline gives the best acceleration up to 500 r.p.m., at which speed reversal of order occurs because of over-richness. Since in this manifold the liquid gasoline goes down by aid of gravity plus the drag due to the airstream, the effect of "loading" would not be as pronounced as with the updraft manifold.

As a further illustration, four curves for Engine *G* operated at factory carbureter-setting with accelerating device are shown in Fig. 16. The two curves for the updraft manifold show better acceleration in the lower speed-range, the curve with heat on having the advantage up to about 600 r.p.m., when reversal of order occurs. It will be seen that these updraft curves show a decrease in acceleration above 700 r.p.m. for the reason before stated.

The effect of an accelerating charge when the main jet is supplying a mixture leaner than is required for maximum power is shown in Fig. 17. The main jet supplied a mixture ratio of 15.9:1 and, when the accelerating charge was being supplied, the mixture ratio was 9.4:1. The improvement resulting from accelerating charges of 2½ and 5-sec. duration is apparent on comparison with the curve representing no accelerating charge. The computed maximum acceleration is also shown.

The effect of changing the amount of accelerating charge while maintaining the carbureter at factory set-

[6] See S.A.E. JOURNAL, September, 1928, p. 240; also TRANSACTIONS, vol. 23, part 2, 1928, p. 342.

ting is shown by Fig. 18. Without an accelerating device, the initial acceleration is small but increases to a value of 128 r.p.m. per sec. at 1000 r.p.m., which is slightly more than the computed maximum acceleration. The summer setting of the accelerating device gives a high initial acceleration, but the acceleration at 1000 r.p.m. is less than without the accelerating device. With the winter setting of the accelerating device, acceleration is still higher initially and lower at 1000 r.p.m. than in either previous case.

The effect of heat on the manifold is indicated in Fig. 19 by acceleration curves obtained for Engine *E* with heat on and off. The heat-on curve shows a higher initial acceleration than the heat-off curve, but at about 800 r.p.m. the curves cross and the heat-off curve gives the highest acceleration beyond that speed. The computed maximum-acceleration curve is also plotted. It will be seen that the utility of acceleration curves is much increased when the shape of the computed maximum curve is known. As the inertia of the engine parts was not known in most cases, the values used were estimated from available data. For this reason the location of the computed maximum-acceleration curves may be in error, but this error does not change the shape of the curve.

Curves for factory setting, with and without heat and accelerating device, are shown on Fig. 20 for Engine *A*, using the downdraft manifold. These show that the heat and accelerating device improve the acceleration up to about 500 r.p.m., but that a reversal occurs at higher speeds; so that the maximum acceleration is 86 r.p.m. per sec., whereas the acceleration shown in Fig. 15 for the same engine, carbureter, and manifold, with no accelerating device and a leaner effective mixture-ratio, reaches 108 r.p.m. per sec. at 1000 r.p.m.

The effect of heat is also shown by curves plotted in Fig. 16 from data obtained with Engine *G*, using updraft and downdraft manifolds. The fact that Engine *G* has a different number of cylinders and a different make of carbureter and manifold than Engine *A* may be of interest. Attention is called to the difference between the updraft and downdraft-manifold curves; although the curves for Engine *G* were taken at factory settings of the carbureter while those for Engine *A* (Fig. 20) were obtained without accelerating devices, the same effect is noticed. The low initial acceleration for the downdraft manifold on Engine *G* (Fig. 16) shows that the accelerating charge was too small, since the carbureter venturi was larger than that of the updraft carbureter. The use of too small an accelerating charge is believed to be due to the customary method of measuring the acceleration.

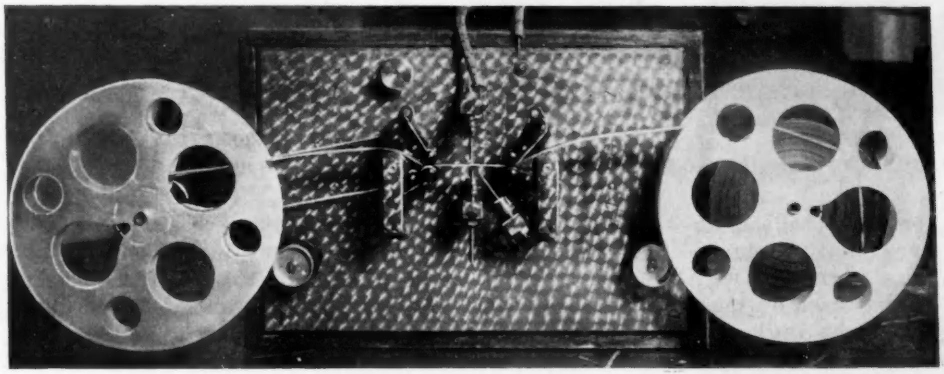


FIG. 26—PORTABLE MODEL SPARK-ACCELEROMETER, FRONT VIEW

Fig. 21 shows the speed-time curves corresponding to the acceleration curves shown in Fig. 16 for Engine *G* using updraft and downdraft manifolds. It is seen from Fig. 21 that the updraft and downdraft curves would reach 1400 r.p.m. in about the same elapsed time, approximately 7 sec., while the computed maximum would reach 1400 r.p.m. in about 5 sec.

These curves show that the elapsed-time method does not give enough information to properly set an accelerating charge to the best possible advantage. With a method giving the acceleration curve, the proper conditions could be found to give best acceleration throughout the speed range, since the exact effect of the accelerating charge can be measured.

To give an idea of the precision of the spark accelerometer when operated under favorable conditions, Figs. 22 and 23 are included, showing respectively the speed-time and acceleration-speed curves obtained on a test made at the Bureau of Standards.

Additional curves are presented to demonstrate the effect of volatility both with and without accelerating devices and also with factory setting of the carbureter and at factory recommended temperature. Curves for Engine *D*, using U. S. Motor gasoline, and Aviation gasoline and a blend of the two are shown in Fig. 24. The curves at low speeds are in the order of the fuel volatilities and cross at the higher speeds, as did those of Fig. 15 for Engine *A*. The same effect is seen by the curves for Engine *B* shown in Fig. 25.

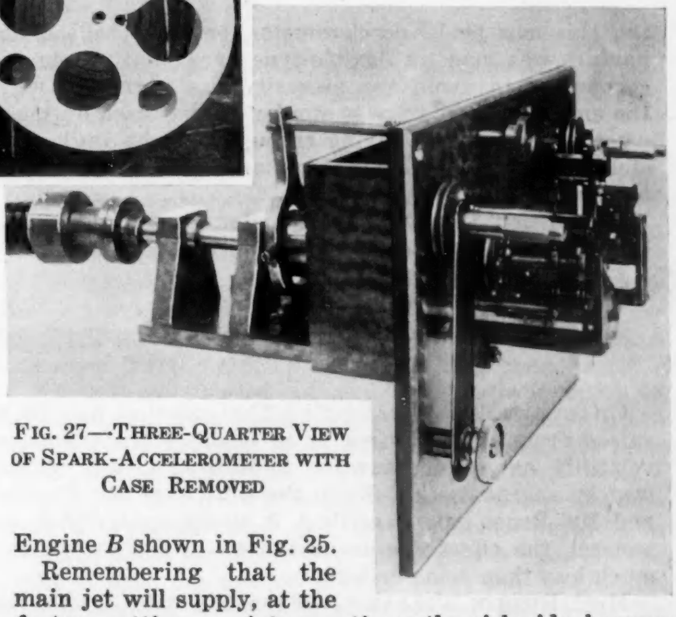


FIG. 27—THREE-QUARTER VIEW OF SPARK-ACCELEROMETER WITH CASE REMOVED

Remembering that the main jet will supply, at the factory setting, a mixture ratio on the rich side, because the carbureter is set for maximum power, it is seen that the addition of heat, accelerating charges and increase in volatility of the fuel all serve to increase the acceleration at engine speeds below about 700 r.p.m. but to decrease the acceleration at higher speeds because of excessive enrichment. This shows the importance of obtaining the acceleration curve.

APPENDIX 1

To expedite the obtaining of the acceleration data by the four automobile companies, it was necessary to construct a portable model spark-accelerometer. This instrument was designed on the basis of the old spark-accelerometer[7] which is, briefly, an engine-driven tape punctured every 1/6 sec. by a high-tension electric current. The change in the distance between punctures is a measure of the acceleration.

Although several minor changes were made in designing this new model accelerometer, only one radical departure was made, a flexible-type drive-shaft being incorporated to avoid the necessity for alignment with the engine. This drive is similar to that used on tachometers and makes driving through a right angle possible. As the cable is 5/8 in. in diameter, it has sufficient torsional rigidity.

In addition, the new accelerometer, shown in Fig. 26, has a take-up reel, driven by a spring belt, for automatically winding up used tape, coming from the supply spool on the right, after it passes between the electrodes.

The self-adjusting clutch is mounted integrally with the accelerometer, as can be seen in Fig. 27, which also shows the flexible drive connected to the accelerometer. Other details are essentially identical with the first model, which was described in a previous paper[8].

The tuning-fork, shown in Fig. 28, was specially built for this work. It is a 6-cycle fork, operating on 5.5 to 7 volts and drawing a mean current of 0.29 amp. It has positive-break contacts similar to the fork used in previous work. Fig. 29 is a diagram of the electrical connections.

The design of a disc to have inertia representing that of an automobile is described by W. S. James[9] in an appendix to a paper by Roger Birdsell on Economic Motor-Fuel Volatility.

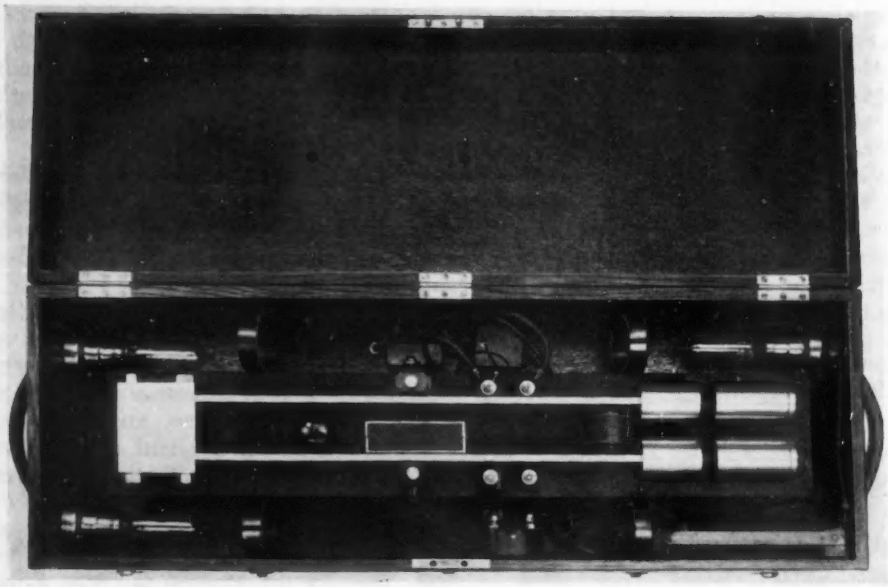


FIG. 28—TUNING-FORK SPECIALLY BUILT FOR ENGINE-ACCELERATION TESTS

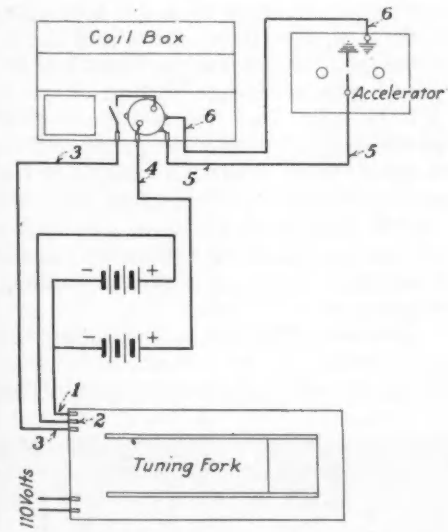


FIG. 29—ACCELEROMETER WIRING DIAGRAM

THE DISCUSSION

CHAIRMAN W. S. JAMES[10]:—The question has been raised from time to time as to whether the influence volatility has on acceleration is affected in any major way by engine design. From the work that Mr. Brooks and Mr. Bruce have described, it would appear that, in general, the effect due to variations in design is very much less than some believe.

MERL RUSKIN WOLFARD[11]:—From the slides thrown on the screen the manifolds used seemed to be very similar. Apparently they were all on six-cylinder engines.

C. S. BRUCE:—Two were eight-cylinder manifolds with four branches.

MR. WOLFARD:—The branching seemed to be similar in all cases. I think that this is a very important point and has more effect on acceleration than has the type of engine. The size of the passages and shape of the manifold have a very important effect.

PROF. GEORGE G. BROWN[12]:—We find that, when about 10 per cent of the fuel is actually vaporized, 30 or 40 per cent of the fuel may be carried in as a mist or liquid. If we are accelerating with the choke drawn out, the 10-per cent point on the A.S.T.M. distillation then corresponds to about 30 or 40 per cent of the fuel actu-

(Concluded on p. 484)

[7] See S.A.E. JOURNAL, June, 1929, p. 609.

[8] See *Bulletin of the American Petroleum Institute*, Jan. 3, 1929, section 2, p. 143.

[9] See THE JOURNAL, March, 1924, p. 271; also TRANSACTIONS, vol. 19, part 1, 1924, p. 145.

[10] M.S.A.E.—Research engineer, Studebaker Corp., South Bend, Ind.

[11] M.S.A.E.—Engineer in charge of research, Hopewell Brothers, Watertown, Mass.

[12] M.S.A.E.—Professor of chemical engineering, University of Michigan, Ann Arbor, Mich.

Comparison of Antiknock Ratings Determined in Different Laboratories

By C. H. Barton[1], C. H. Sprake[2] and R. Stansfield[3]

Annual Meeting Paper *Illustrated with* Charts

TESTS conducted about a year ago in the laboratories of three British oil companies to ascertain the antiknock properties of fuels, with the object of obtaining uniformity in expression of antiknock values, are described and the results compared.

Nine gasolines of qualities normally obtainable in the British market were used in the tests and the results are expressed in terms of percentage by volume of equivalent blends of heptane and pure benzene. Each laboratory followed its own standard method of testing and, to ensure uniformity, the supplies of heptane and benzene were bulked and redivided before use.

The report on the results refers to tests with a Delco, an Armstrong-Whitworth and a Ricardo E-35 engine. Test procedures followed in the several laboratories are described and the results obtained are compared in graphs. Average and maximum deviations of the three laboratories from the mean of the values obtained are tabulated, as are also the average differences, in percentage of benzene, for four fuels of highest antiknock value and for all nine fuels. Maximum deviation of the average of results obtained by each laboratory from the mean of results in all three laboratories range from +2.1 to −2.2 per cent benzene. Agreement among individual results is not so satisfactory for fuels of higher antiknock value as for those of lower value, the average differences for four of the former ranging from 0.85 to 3.10 per cent of benzene in the three laboratories, whereas the difference range for all nine fuels tested is from −0.10 to + 1.60 per cent benzene.

The tests show that, within the very narrow limits investigated, very concordant knock ratings for different fuels can be obtained with engines of widely different design and working conditions if temperature and speed are carefully controlled and settings are adjusted for maximum-knock mixture-strength.

TOWARD the end of 1928 a cooperative committee was formed from the technical staffs of the Anglo-American Oil Co., the Anglo-Persian Oil Co. and the Asiatic Petroleum Co. to discuss and compare the methods used by the three companies for testing the antiknock properties of fuels, with the object of obtaining uniformity in expression of antiknock value. The tests described in the present paper were carried out about a year ago.

As a result of a preliminary discussion, it was decided to put in hand tests in the laboratories of the three companies on nine gasolines of qualities normally obtainable in the British market and to express results in terms of the equivalent blends of n-heptane and pure benzene. Heptane was chosen as being the only readily available pure hydrocarbon of low antiknock value, while benzene is the obvious choice for a pure hydrocarbon of high antiknock rating. Each laboratory was left free to use its own standard method of testing, and, to ensure uniformity of standards, the supplies of heptane and benzene available were bulked and redivided before use.

The final report on the test results refers to three engines: a Delco plant used by the Anglo-American Oil Co., an Armstrong-Whitworth plant used by the Anglo-Persian Oil Co., and a Ricardo E-35 unit used by the Asiatic Petroleum Co.

Details of all these sets have been published from time to time in the technical press.[4]

Anglo-American Oil Co.'s Tests

The engine is of 2½-in. bore by 5-in. stroke, giving a swept volume of 402 cc. (24.53 cu. in.), and the compression ratio is 7.5 to 1. The cooling is by water and works on the evaporative system, with control of the temperature of condensate return to the base of the cylinder, which is maintained at 100 deg. fahr.

The ignition, which is by 32-volt Delco coil, is set for maximum power at a speed of 600 r.p m. and is run from a 32-volt battery which is kept charged by the engine generator and is also used for starting and for operating the electrolytic cell, or voltameter.

Detonation is measured by the Midgley bouncing pin and electrolytic cell, the pin being set just to give no gas generation at 600 r.p m. on a non-pinking fuel using the same throttle setting as for the fuel under test.

All tests are carried out using a mixture strength to produce maximum knock, and the throttle is set to obtain a gas generation of approx mately 0.5 cc. per min. with the fuel under test.

A special feature of the engine is the carbureter system, which consists of two float-chambers working on vertical slides and fitted with gage glasses showing the level of the fuel against a fixed scale, the float chamber being fed from inverted overhead bottles on the chicken-fountain principle. Flexible pipes connect the float chamber to the jet-supply chambers, and instantaneous change-over from the reference fuel to the fuel under test is effected by a three-way cock fitted close to the jet. Working within its limits, that is, from the weakest mixture to the level at which the jet overflows,

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[1] Asiatic Petroleum Co., London, England.

[2] Anglo-American Oil Co., London, England.

[3] Anglo-Persian Oil Co., London, England.

[4] For E-35 engine see Report of Empire Motor Fuels Committee, issued by the Institute of Automobile Engineers (London), 1924, p. 63, and *The Automobile Engineer*, February to August, 1921. For Armstrong engine see *Industrial and Engineering Chemistry*, annual edition, April 15, 1929. For Delco engine see *National Petroleum News*, Oct. 23, 1929, p. 57.

this system is very sensitive to changes in antiknock values, a difference of approximately 0.1 cc. in gas generation for 1-min. runs being obtained for the addition of 1 per cent benzene to a given fuel. The electrolytic cell is graduated in hundredths of a cubic centimeter, and 0.1 cc. is the capacity of approximately 3/8 in. of the graduated tube. This system obviates the possible instability of variable jets and is readily reproducible.

The engine is direct-coupled to a 1250-watt dynamo, the output from which is absorbed by a fixed resistance. The engine speed can be closely controlled by a voltage regulator, and all the tests described later were made at a speed of 600 r.p.m.

In making tests, alternate runs of 1 min. are taken on the reference fuel and the fuel under test, and the correct mixture of reference fuels to equal the fuel under test is found by trial and error.

In the present series of tests, a number of mixtures of benzene and heptane were matched against a fuel of low antiknock value plus ethyl fluid, and the fuels under test were first matched against this low-grade fuel plus ethyl fluid so as to minimize the quantity of heptane required. When the approximate benzene-heptane values of the fuels had been found in this way, check tests were carried out comparing the various fuels directly against the benzene-heptane value thus arrived at, with slight adjustments in the proportions of benzene to heptane where necessary.

Anglo-Persian Oil Co.'s Tests

The Armstrong-Whitworth plant includes a 2 7/8-in. bore by 3 1/2-in. stroke side-valve engine having a cylinder-head fitted with a sliding plug which can be moved to vary the compression ratio between the limits of 4:1 and 8:1. The lower end of this plug is arranged to take the diaphragm of a Midgley bouncing-pin indicator. The water system is divided to give separate cooling for the head and the jacket, and an electric heater is fitted for the inlet air. The fuel is fed through a single adjustable jet from any of the three flowmeters, and the flow is arranged to be direct from the meters without float chamber or weir. Tests are made at full throttle, the compression ratio being adjusted by means of the variable-compression plug to give continuous knocking of a degree sufficient to operate the bouncing-pin indicator with the gasoline under test.

The following are the normal working conditions of the test:

Engine speed, r.p.m.	750
Temperature of water-outlet from jacket and cylinder-head, deg. fahr.	120
Air-inlet temperature, deg. fahr.	120
Ignition advance, deg.	12

No alteration is made to ignition advance with change of compression ratio.

The sample to be tested is run from one of the flowmeters and the compression ratio is adjusted until the knocking is of standard intensity. The ratio necessary for this indicates approximately the value of the gasoline in terms of a blend of benzene and heptane. Two standard blends are then made, one slightly lower in antiknock value than the sample and the other slightly higher and differing by 2 per cent of benzene in heptane. Voltameter gas-collections over successive 1-min. intervals are then taken from each of the standard blends and the sample, the air-fuel ratio being adjusted in each case to give maximum knock.

The value of the sample in terms of the two standard hydrocarbons is then calculated from the ratio of the gas difference between the two standard blends and the difference between the lower of these and the sample; thus, if the gas difference between a 60-per cent benzene and 40-per cent heptane blend and a 62-per cent benzene/38-per cent heptane blend is 0.50 cc., and the

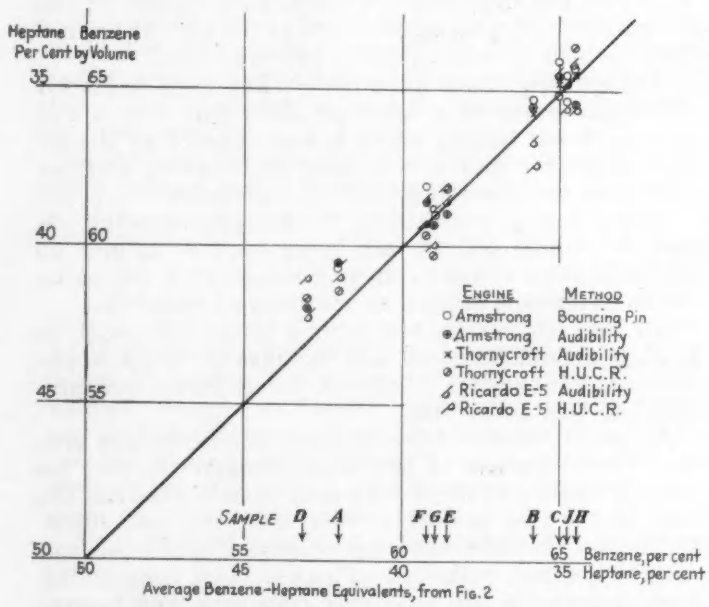

FIG. 1—RESULTS OF ANTIKNOCK TESTS ON THREE ENGINES IN LABORATORY OF ANGLO-PERSIAN OIL CO.

Results of the Individual Tests Are Plotted against Mean Values Obtained from the First Series of Tests. The Maximum Deviation Was 2.2 Per Cent Benzene, and the Average Deviation for 54 Tests Was 0.24 Per Cent from the Average Values Obtained by Three Laboratories

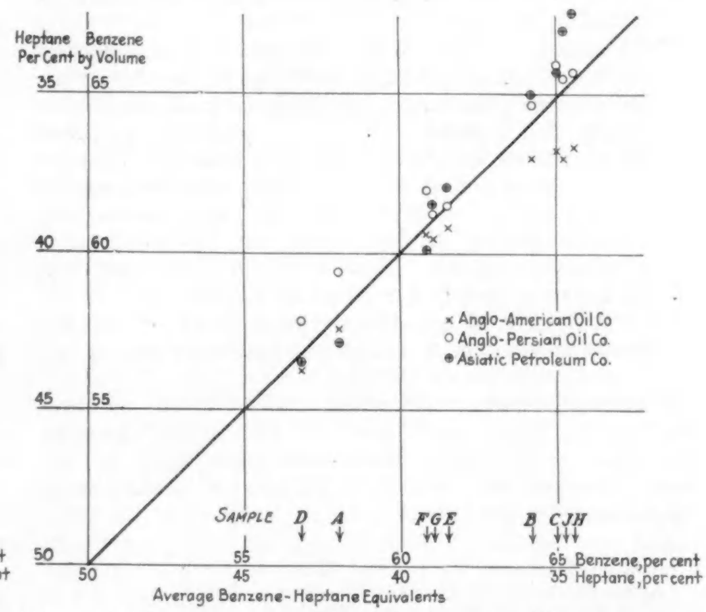

FIG. 2—RELATION BETWEEN INDIVIDUAL TEST-RESULTS OBTAINED IN THREE LABORATORIES AND AVERAGE ANTIKNOCK VALUES

Antiknock Values Assigned to Various Benzene-Heptane Blends by Each Laboratory, after Completion of Tests, Were Averaged and Plotted as Shown. The Extreme Deviation from the Mean Ranges from +2.1 Per Cent to —2.2 Per Cent Benzene

difference between the 60-40-per cent blend and the sample is 0.10 cc., the sample is rated as 1/5 of 2-per cent benzene better than the 60-40-per cent blend; that is, as 60.4 per cent benzene and 39.6 per cent heptane. This procedure is repeated at least three times and the mean value taken as the result of the test. Values are not appreciably affected by small changes of speed, although this is maintained constant to within ± 5 r.p.m. The allowable temperature variation for water and inlet-air is ± 1 deg. fahr.

In addition to bouncing-pin tests, the Anglo-Persian Oil Co. made determinations on a 1-liter (61.022-cu. in.) capacity overhead-valve Thornycroft engine running at 1200 r.p.m. and on a Ricardo E-5 sleeve-valve engine of 350-cc. (21.357-cu. in.) capacity running at 1750 r.p.m. Both of these engines were of the variable-compression type, and these further runs included audibility tests and tests for highest useful compression-ratio. The results are plotted on Fig. 1 against the mean values obtained from the first series of tests. The maximum deviation was 2.20 per cent benzene, and the average deviation for 54 tests was 0.24 per cent benzene from the average values obtained by the three laboratories.

TABLE 2—ANALYTICAL DATA ON FUELS TESTED

	A	*B*	*C*	*D*	*E*	*F*	*G*	*H*	*J*
Specific Gravity, at 60 deg. fahr.	0.739	0.727	0.728	0.735	0.738	0.743	0.727	0.732	0.724
Initial Boiling-Point, deg. cent.	37	28	35	38	35	37	39	41	40
Volume Distilled to, Deg. Cent.									
50, per cent	2	8.5	5	3	3.5	3.5	1	f.d.	f.d.
75, per cent	16	25	20	17.5	16	13.5	21	14	16
100, per cent	46	43	39	36.5	34.5	27.5	66.5	56	63
125, per cent	71	63	64	59	56	48.5	91	86	91
150, per cent	89	80	83	79	77.5	70		96	97
175, per cent	96.5	92	93	93	91.5	89.5			
200, per cent		96.5							
End-Point, deg. cent.	180.5	202	187	195	199	197	149	157	152
Total Distilled, per cent	98.0	97.5	96.0	98.0	97.5	97.0	98.0	97.5	97.5
Residue, per cent	1.0	1.0	1.2	1.0	1.1	1.0	1.1	1.0	1.0
Loss, per cent	1.0	1.5	2.8	1.0	1.4	2.0	0.9	1.5	1.5
Aromatics, per cent by volume	18.1	6.9		10.6	9.1		16.6	10.8	7.0
Critical Solution Temperature									
Before Acid, deg. fahr.	46.20	52.70	[a]	52.30	52.10	[a]	46.20	47.00	50.40
After Acid, deg. fahr.	64.15	59.65	[a]	62.85	61.16	[a]	62.95	57.80	57.55

[a] Contains cracked fuel.

Asiatic Petroleum Co.'s Tests

The procedure in carrying out the tests with the E-35 engine, which has a bore and stroke of 4½ x 8 in., is as follows:

After warming-up the engine thoroughly by running it on a standard fuel, the compression ratio is set to 4.5 to 1 and the throttle fully opened. The engine speed is then adjusted to 1500 r.p.m., which is the speed at which this engine develops its maximum torque, and the fuel is changed over to the gasoline to be tested, after which the highest useful compression ratio is determined under the following engine conditions:

Full throttle

Speed, 1500 r.p.m. (= 2000 ft. per min. piston speed)

Heat input to induction system, by means of electric heater in air intake, adjusted to 76.7 B.t.u. per min. (1350 watts)

Water-jacket temperature, deg. cent 55 ± 1

Mixture strength delivered by carbureter adjusted to give maximum power output

Ignition advance adjusted to the optimum advance for the compression ratio at which the engine is running. (A calibration curve showing the optimum ignition-settings over the whole range of compression ratio has been previously determined, using a gasoline giving no detonation.)

With all the foregoing conditions carefully maintained, the compression ratio is gradually raised and for each small increment the ignition is re-set according to the optimum curve. This procedure is continued, the power output being recorded, together with remarks about intensity of audible detonation, at each increase in compression ratio until the detonation intensity reaches "frequent moderate." The power output is a maximum at this point; that is, any further increase in compression ratio produces heavier detonation and the power output no longer increases. The compression ratio reached at "frequent moderate" detonation is the observed highest useful compression-ratio.

Owing to the variations which occur from day to day in barometric and temperature conditions, the observed H. U. C. R. must be corrected to a common standard. A check test is therefore run on a standard (straight-run) fuel of medium volatility; that is, distilling about 30 per cent up to 100 deg. cent. (212 deg. fahr.) and having an end-point of about 200 deg. cent. (392 deg. fahr.) in the A.S.T.M. distillation. The difference between the observed value on the check test and the arbitrary H.U.C.R. value attached to the standard fuel is then added to the value of the sample under test to obtain the corrected H.U.C.R. of the sample.

The method used provides two observations at the "observed H.U.C.R." One is the audible indication which is readily appreciated by an experienced observer and the other is the marked discontinuity in the curve of engine torque, or power, and compression ratio. This discontinuity is very marked at the H.U.C.R. if the engine conditions as described are maintained. The error of the method is found to be 0.03 H.U.C.R. unit. This corresponds with the effect of about 0.6 per cent benzene in a mixture of 60 per cent benzene with 40 per cent heptane by volume.

In the present tests the corrected H.U.C.R. of each

TABLE 1—CONTENT OF BENZENE IN BENZENE-HEPTANE MIXTURES TO MATCH FUEL UNDER TEST, PERCENTAGE BY VOLUME

	Tests Made by			
Gasoline	Anglo-American Oil Co.	Asiatic Petroleum Co.	Anglo-Persian Oil Co.	Average
A	57.5	57.1	59.3	58.0
B	63.0	65.0	64.7	64.2
C	63.5	65.7	65.9	65.0
D	56.2	56.4	57.7	56.8
E	60.7	62.1	61.4	61.4
F	60.5	60.0	62.0	60.8
G	60.3	61.4	61.2	61.0
H	63.3	67.6	65.7	65.5
J	63.0	67.0	65.5	65.2

fuel was determined by the method described. The equivalent blends of benzene and heptane were read off from the curve showing the previously ascertained relation between H.U.C.R. and percentages of benzene and heptane. Finally, each of the nine equivalent blends of benzene and heptane were made up and direct comparisions by further engine tests were made, each sample being tested consecutively to its equivalent benzene-heptane blend. The final value given to each sample was, therefore, checked and corrected by comparative tests made at very nearly the same compression-ratio.

Discussion of Results

On completion of the tests the values assigned by each laboratory were averaged. Fig. 2 shows the results plotted against the average for each gasoline. The extreme deviation from the mean was + 2.10 per cent benzene in one case and — 2.20 per cent in another case. The average and maximum deviations of the three laboratories are shown in the following table:

Laboratory	Average Deviation from Mean in Per Cent of Benzene Content	Maximum Deviation from Mean in Per Cent of Benzene Content
Anglo-American	1.10 below	2.20 below
Asiatic Petroleum	0.50 above	2.10 above
Anglo-Persian	0.60 above	1.30 above

The agreement between individual results is generally less satisfactory for fuels of higher antiknock value than for those of lower antiknock value. This is shown by the table at the top of the next column.

Laboratories	Average Difference for Four Fuels of Highest Antiknock Value, Per Cent of Benzene	Average Difference for All Fuels, Per Cent of Benzene
Asiatic Petroleum and Anglo-American	3.10	1.60
Anglo-Persian and Anglo-American	2.25	1.70
Asiatic Petroleum and Anglo-Persian	0.85	−0.10

It is evident from these figures that a mean curve through the Anglo-Persian and the Asiatic Petroleum Co.'s results would tend to diverge upward at the higher points from the line shown in the diagram, while the curve through the Anglo-American Co.'s results would diverge downward at the high results. There is at present no obvious explanation for these differences between the results, on the highest antiknock fuels, of the Armstrong and E-35 engines, on the one hand, and those of the Delco engine, on the other hand. It seems scarcely likely that the difference in throttling accounts for the disagreement, since, with the highest antiknock fuels, the difference between the Delco and the other engines in this respct is less with these fuels than with the fuels of lower antiknock value.

The tests are of interest as showing that, within the comparatively narrow limits represented (57 per cent benzene in 43 per cent heptane to 67 per cent benzene in 33 per cent heptane), very concordant knock ratings of different fuels can be obtained with engines of widely different design and working conditions, provided the settings in all cases are properly adjusted for maximum-knock mixture-strength and that a careful control of the engine conditions, that is, temperatures and speed, is maintained, to assure uniformity throughout the series of tests.

The engine results are shown in Table 1, and the distillation tests and other data of the gasolines are given in Table 2.

THE DISCUSSION

CHAIRMAN H. L. HORNING[5]:—During the year, through the efforts of T. A. Boyd, a situation entered into the standard testing method that is being developed in the Cooperative Fuel Research Committee, by which it was possible to secure a considerable amount of interest from three of the best-known British oil companies in the work of our American Committee, the idea being that, if we develop a standard method here, it would be well to have the British oil industry also interested so that we might be that much nearer a world standard. We had in mind something else than selfishness, and I am sure Mr. Boyd did too; namely, that the British companies had done a great deal of work of a very sound nature that would help us perhaps to make some short-cuts and save us some time.

As a result of correspondence, the work is converging toward a common ground, and the paper by the three gentlemen connected with these companies has to do with the subject somewhat in general and with what they have found in connection with three different methods. It is necessarily in the nature of a progress report and throws out the definite hope that, as we explore the various regions in connection with this matter, some day, in some way, it will be possible for us to come to a standard testing method.

DR. H. C. DICKINSON[6]:—I had the privilege of seeing the laboratories of the Anglo-American and the Anglo-Persian companies near London in the summer of 1929 and can say that all the men whom I met there are most intensely interested in the work that is going on over here. They have offered us the fullest cooperation. I believe it is very desirable for us to keep in touch with those laboratories. A great many very interesting pieces of work are going forward on various phases of the problem of detonation about which we shall doubtless hear from time to time.

Close Agreement of Laboratory Results

T. B. RENDEL[7]:—The company I represent has at its Wood River refinery a similar type of engine and employs a method similar to that of the Asiatic Petroleum Co. We also correct our results with a standard fuel.

Some time ago we ran a series of tests using normal heptane and toluene and also normal heptane and iso-octane and plotted the H.U.C.R. (highest useful compression-ratio) results, both uncorrected and corrected to a standard fuel which we obtained from London, versus the percentage of toluene or iso-octane in normal

[5] M.S.A.E.—President, general manager, Waukesha Motor Co., Waukesha, Wis.; member, Cooperative Fuel Research Steering Committee.

[6] M.S.A.E.—Chief, engine and power division, Bureau of Standards, City of Washington; member, Cooperative Fuel Research Steering Committee.

[7] Jun.S.A.E.—Motor testing, research engineer, Shell Petroleum Corp., St. Louis.

heptane. For given percentages of toluene we found that the observed highest useful compression-ratio, without correcting, was slightly lower all the way through than that obtained by the Asiatic company in London. However, the two curves ran practically parallel. After correcting the two fuels, the two curves coincided, showing a remarkable agreement between the two engines.

On checking up the results obtained by the General Motors Corp. laboratory, as presented in Mr. Campbell's paper[8], I find that our results agree very well with its results also. In fact, comparing the percentages of toluene in heptane required to equal given percentages of iso-octane in normal heptane for percentages between 30 per cent iso-octane in heptane and 70 per cent iso-octane in heptane, we differ by a maximum of 2 per cent. Considering the agreement Dr. Brown also reported[9] and the wide divergence in engine and operating conditions, I think this argues very favorably for the variable-compression method of measuring the detonation tendency of a motor fuel.

OTTO C. ROHDE[10]:—Is there any evidence of a difference between the antiknock characteristic of the ethyl gasoline at present used and that used about a year ago?

T. A. BOYD[11]:—My understanding is that a slight change has been made. The figures have been published[12]. It is a very slight change, equivalent to ¼ cc. more of tetraethyl lead per gallon, as I recall it.

British Test Fuels Not Widely Different

DR. H. K. CUMMINGS[13]:—In the next to the last paragraph of the paper, the narrow limits represented are referred to in parentheses as 57 to 67 per cent benzene. If the results obtained by the three laboratories with the nine fuels tested are averaged, the figures are more nearly 57 to 65.

In any event it is desirable to emphasize, what is fully admitted in the paper, that these nine fuels represent gasolines that do not differ very much and the results are, therefore, comparable with the agreement now being obtained by many laboratories in this Country in the course of routine testing of commercial gasolines, rather than what has been obtained and is likely to be obtained on more diverse fuels covering a wider range of antiknock value. The deviations mentioned of 2 and 3 per cent of benzene, are 2 and 3 in a total of about 9 per cent, so the differences between laboratories on the same sample are often about 25 per cent of the whole difference between the best and worst fuels.

Test Method Without Engines Desirable

W. S. JAMES[14]:—Has any recent work been done on methods of measuring knock characteristics of fuels without using engines? Considerable progress has been made toward the development of an engine as a piece of laboratory equipment, but I think that considerable difficulty is involved, generally, in the use of that type of equipment. Is any work being done, parallel with this engine-development work, toward the working out of a test to indicate detonation characteristics without the use of engines?

CHAIRMAN HORNING:—At a certain stage of the program a proposal was made that such a method be thought out, but members of the Committee saw things in the dark when that was proposed. They always reverted to the question of the many variables that enter when an engine is running and to the effects of the receding piston on detonation and to temperatures and other factors. They finally thought it best to proceed as far as possible, at least for the initial tests, with the standardizing of the engines rather than having a test developed that was outside the province of the engine.

DR. DICKINSON:—Several years ago a considerable amount of work was done at the Bureau of Standards along the line suggested. It was undertaken at the request of the Navy Department and some quite interesting results were obtained in various studies of the possibility of determining the detonation characteristics in a constant-volume enclosure.

One would hardly dare say that there is any real prospect of devising a satisfactory laboratory test for detonation characteristics. At least in our laboratory we did not go far enough to suggest even a guess as to that possibility. However, I think the problem is sufficiently interesting to warrant carrying it on sometime, and I hope that if no one else undertakes it we may have an opportunity of studying further the possibilities of such a laboratory test-method. At present, and for the last two years or so, we have not been able to go ahead with that work, not having available appropriations or the personnel for it. At some time in the future it may be possible to do so.

Gasoline Engine a Sensitive Analytical Chemist

MR. BOYD:—In connection with but not at all in answer to Mr. James's question, I think we sometimes do not appreciate how sensitive the gasoline engine is. The fact that we do not always agree in the results we get is probably due largely to variations in the technique and the conditions under which we get them. The gasoline engine is a very precise analytical chemist; which, of course, proves that it is not always necessary to have brains to be a chemist.

The gasoline engine can definitely tell the difference between a fuel containing, say, 3 cc. of tetraethyl lead per gallon and one containing 2.8 cc. That may not seem to be so sensitive, but one must bear in mind that the gasoline engine analyzes a gasoline by taking 100,000 to 200,000 sips from each gallon. Although the engine weighs say 500 lb., the sensitivity it gets is about 0.2 cc. or 0.33 gram of lead tetraethyl per gallon. If we divide this amount by 150,000 we get 0.000002 gram. That is only 1/500th of a milligram, which is beyond the sensitivity of the best chemical balance in any of our laboratories.

In the case of benzol, we should like to have a device that would detect the difference of ½ per cent of benzol. That can be done under good conditions, depending upon the range in which it is done. One-half per cent of benzol is about 20 cc. per gal. If we treat that on the same basis, we find that the sensitivity of the engine in benzol is about 0.00012 gram, which is about 0.1 milligram, and an amount below the limit of accuracy for the ordinary chemical balance.

[8] See S.A.E. JOURNAL, February, 1930, p. 163.

[9] See S.A.E. JOURNAL, April, 1930, p. 485. (G. G. Brown disc on Campbell-Lowell-Boyd.)

[10] M.S.A.E.—Chief engineer, Champion Spark Plug Co., Toledo, Ohio.

[11] M.S.A.E.—Head of fuel section, General Motors Corp. Research Laboratories, Detroit.

[12] See *National Petroleum News*, July 31 and Aug. 7, 1929.

[13] S.M.S.A.E.—Physicist, chief of automotive powerplants section, Bureau of Standards, City of Washington.

[14] M.S.A.E.—Research engineer, Studebaker Corp., South Bend, Ind.

MR. HORNING:—I am sure that we all appreciate the viewpoint which Mr. Boyd has presented. I agree with him that it is remarkable how sensitive the engine is. We had an assistant who came into our laboratory and was not familiar with the antiknock qualities. Mr. Boyd had given us a bottle of foul-smelling onion-garlic antiknock mixture and somebody had spilled this precious liquid. One of the men got it on his clothes. He happened to be the man delegated to show this novice how delicately he had to work with the scales on the dynamometer. As an illustration of the sensitivity that Mr. Boyd has mentioned, I want to say that when this man with some of this garlic on his clothes was on one side of the engine the scale was down, and when he went to the other side the scale would come up.

That may sound like nonsense, but it is not. The man absolutely demonstrated many times that the scale beam would record his position with relation to the engine. He would stand alongside the carbureter and the beam would very definitely rise fast. I think that is a most remarkable demonstration of the sensitivity of an engine to antiknock material; but if you could smell some of the stuff, you would not think the engine was over-sensitive.

Mixture Distribution

(Concluded from p. 470)

measurement may be shown, (*b*) the actual effect of the many factors can be determined and (*c*) everyone may present definitely superior products that will give more economical and satisfactory service?

MR. TAUB:—Professor Jacklin states that I mentioned but two methods for measuring the quality of our distribution—exhaust-gas analysis and the spectroscope—overlooking the fact that the entire first part of the paper is devoted to a simple graphic means of checking distribution. He states also that we have overlooked the indicator card as a means for determining distribution. Reference to indicator cards has been omitted, but their possible use has not been overlooked as an aid to distribution. We have tried indicator cards, one cylinder at a time and all at one time. We find the high-pressure side value less because, when single-cycle cards are made, the maximum pressure varies greatly in one cylinder between cycles. When a composite card is made, so many spots are found that the end does not justify the means. Under the best of conditions taking cards at the maximum-economy point is necessary because the maximum pressure does not vary in readable quantities up to 10 per cent over-rich, and therefore all variations must be on the lean side. On the low-pressure side we have found that the valve-lash variation upsets the card and that deductions to be drawn are more likely to be on the effect of the camshaft rather than of the pipes, ports or carbureter. The low-pressure card that pictures the induction and exhaust cycle can hardly be expected to indicate which cylinder induces a wetter mixture.

I heartily agree with Professor Jacklin's comments on the need for concerted action to determine how distribution can be bettered.

Effect of Design on Engine Acceleration

(Concluded from p. 478)

ally brought into the cylinders during the acceleration period. If a car is being driven with the choke, a low 10-per cent point will satisfy all acceleration requirements of the engine at low temperature. As the temperature goes up, the choke is not used, a leaner mixture is supplied at the carbureter and it is necessary to effectively vaporize more of the fuel. When 35 per cent is vaporized, we shall be delivering about 45 to possibly 50 per cent of the fuel to the cylinders, which, when an accelerating device is provided, is adequate for all ordinary acceleration without the choke. The performance during the warming-up period then is indicated by the 35-per cent point on the A.S.T.M. distillation. After the engine is warmed up under usual driving conditions, about 50 to 55 per cent on the A.S.T.M. distillation is being vaporized, which indicates satisfactory acceleration of an engine that is warm and equipped with an accelerating device and a heated manifold. The changes in the 85 or 90-per cent point have no effect on the acceleration if the carbureter has an accelerating device.

The January, 1930, issue of the S.A.E. JOURNAL carries an article[13] by Adrian Hughes, Jr., reporting a series of tests on motorcoaches. He found, with fuels having the same 10 and 50-per cent points but different 90-per cent points, a loss in power and acceleration with use of the low 90-per cent fuels. As far as lowering the 90-per cent point to gain acceleration on modern automotive equipment is concerned, we are barking up the wrong tree.

S. M. UDALE:—Were the downdraft carbureters equipped with downdraft manifolds? If so, how is the difference in the acceleration characteristics between the updraft and the downdraft manifolds explained?

MR. BRUCE:—With the updraft carbureter the air speed has to be sufficient to overcome gravity and take the gasoline into the engine. With the downdraft manifold the air speed needs to be only sufficient to keep the gasoline going, aided by gravity. The curves showed that the lower air-speed got the gasoline in; also, that we did not, in any case, get the loading effect with the downdraft manifold after the air speed in the manifold increased that we got with the updraft manifold.

[13] See S.A.E. JOURNAL, January, 1930, p. 49.

Detonation Characteristics of Some of the Fuels Suggested as Standards of Antiknock Quality

Discussion of the Annual Meeting Paper[1] by John M. Campbell, Wheeler G. Lovell and T. A. Boyd

IN the discussion are given interesting data obtained from work done on the universal testing-engine developed by the National Advisory Committee for Aeronautics, together with a description of the fuel system employed and a chart showing the results obtained in terms of relative compression-ratio based on pure normal heptane. Hydrocarbon mixtures are considered as to their possible use as a basis for making a standard fuel, and the statement is made that some of the presumably undesirable characteristics in such a fuel seem to be eliminated when certain materials are available that, when blended, give virtually a straight-line distillation-curve. The detonation characteristics of the blends are discussed also.

PROF. G. G. BROWN[2]:—Data of interest in comparing the antiknock values of benzene and iso-octane were obtained during the work done on the universal testing engine developed by the National Advisory Committee for Aeronautics. This single-cylinder variable-compression engine has a 5-in. bore and a 7-in. stroke and is different in dimensions from the one used at the General Motors laboratory. It is constructed in much the same way, having overhead camshafts, two inlet-valves and two exhaust-valves, and the compression ratio is varied by raising and lowering the entire cylinder-head and the camshafts by means of a crank.

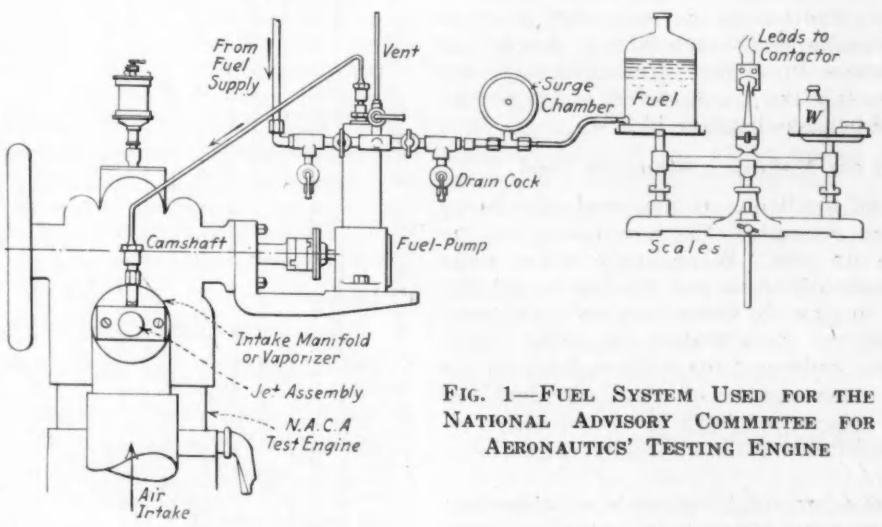

FIG. 1—FUEL SYSTEM USED FOR THE NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS' TESTING ENGINE

Fig. 1 shows the most satisfactory fuel-feed system we have discovered. We tried carbureters and found that the throttles, needle-valves and jets introduced variables which could not be eliminated. The next step was to install a Reeves variable-speed transmission equipped with a small fuel-pump and to drop the fuel directly into the inlet manifold. This seemed to be a step in the right direction, but was not entirely satisfactory. We now use a solid-injection fuel-pump to feed gasoline to a vaporizing inlet manifold. The standard fuel feeds from the main supply-tank.

When making a test, the fuel is weighed through the bottle. Thence, it flows through a rubber hose, a surge chamber to take up the surges from the cut-off of the fuel-pump, and a drain cock. The vent tube serves to vent off the vapors that may form in the fuel line when testing straight natural gasoline or other fuel that vapor-locks badly. From the pump to the manifold, the fuel is under pressure and no vapor lock occurs. The only change necessary was to modify the spring in the fuel-pump so that it would operate at much lower pressure than when operating the engine on a Diesel cycle.

Fig. 2 shows the results obtained in terms of relative compression-ratio based on pure normal heptane. These tests were run in the 5 x 7-in. engine that was cooled by water circulation to an outlet temperature of 175 deg. fahr., instead of employing evaporative cooling at 212 deg. fahr. The spark was maintained constant at a 30-deg. advance and was not varied for different compression-ratios, as was done in the work reported by Mr. Campbell. The mixture ratio also was adjusted for maximum knock and not for maximum power.

Considering these differences in methods, one would expect to find considerably different results but, as nearly as I can judge, the results are very similar to those reported by Mr. Campbell, although the relative compression-ratio will be decidedly different. In other words, heptane knocks at a compression ratio of 3.53:1 under most conditions, instead of at a ratio around

[1] The paper was published in the February, 1930, issue of the S.A.E. JOURNAL, beginning on p. 163. The authors are connected with the General Motors Corp. Research Laboratories, Detroit. Mr. Campbell is research chemist, Mr. Lovell is assistant head of the fuel section, and Mr. Boyd is head of the fuel section. A synopsis of the discussion is printed herewith but the abstract published with the paper is not reprinted.

[2] M.S.A.E.—Professor of chemical engineering, consulting engineer. University of Michigan, Ann Arbor, Mich.

2.75:1, due to the fact that the spark at a 30-deg. advance is too far retarded for maximum power at low compression-ratios, and at high compression-ratios the spark is altogether too far advanced for maximum power. A 30-deg. advance with a compression-ratio of 14:1 at 900 r.p.m. is too much.

But if we compare the relative values between different benzene-heptane blends and iso-octane blends, we find great similarity. Up to 50 per cent by volume, there is no distinguishable difference between blends of benzene and heptane and blends of iso-octane and heptane. The upper line in Fig. 2 is the knock rating determined by raising the compression-ratio to the first audible knock, which is the method reported in Mr. Campbell's paper. The lower line indicates the compression ratio required to give maximum power. I checked one point and it showed a 71 iso-octane value as corresponding with about a 62 benzol-value, as nearly as I could read it from the printed curve, where the curve in Fig. 2 would show 64.

Another point was that 100-per cent iso-octane knocked at about the same compression ratio as does 85-per cent benzene. That is exactly what we have found; that is, 100-per cent iso-octane has the same knocking tendency as a blend containing 85 per cent of benzene and 15 per cent of normal heptane. Considering the different operating temperatures, different spark-advance, that the mixture is set not for maximum knock but for maximum power, and that engines of different speeds and different dimensions are employed, it seems to me that these results check surprisingly closely and indicate that changes in engine dimensions do not markedly upset the relative knock-rating of iso-octane, heptane blends and benzene-heptane blends.

Possibilities for Making a Standard Fuel

ARTHUR L. DAVIS[8]:—All automotive engineers know that the detonation characteristics are based on the composition of the material. When analyses are made of these hydrocarbon mixtures, our limited knowledge usually enables us to classify these materials, the components of the fuel, as unsaturated, aromatic, naphthene and saturated hydrocarbons. Then, because we do not know the exact nature of the individuals in each one of these groups, we have the factor of volatility entering in addition to the characteristics of the group components.

It was thought that we might possibly consider one of these goups as the basis for making a standard fuel. In going over the subject, it is well known that the aromatics seem to have the best characteristics; and, down through the four groups, the paraffins seem to have the most undesirable detonation characteristics. With this in view, pure normal paraffin hydrocarbons—pentane, hexane, heptane, octane, nonane, decane, undecane, dodecane, tridecane and tetradecane—have been either purchased or prepared. Mixtures of equal portions of n-pentane, n-hexane, n-heptane, n-octane, and mixtures of equal portions of n-pentane, n-hexane, n-heptane, n-octane, n-nonane and successive mixtures with the addition of another component n-decane, n-undecane, n-dodecane, n-tridecane and n-tetradecane respectively, have been made and their detonation characteristic determined, principally in connection with the arbitrary standard with which we are all familiar, the value being based upon the number of cubic centimeters of tetraethyl lead per gallon required to bring this paraffin mixture up to the temporary standard.

[8] Chief chemist, Empire Oil & Refining Co., Okmulgee, Okla.

It is interesting to note that these pure hydrocarbon blends have distillation characteristics, as determined by the distillation procedure of the American Society for Testing Materials, that are very similar if not virtually identical in volatility characteristics with the fuels with which we wish to compare them. Therefore, we seem to eliminate some of the presumably undesirable characteristics in the standard fuel when we have certain materials that, when blended, give virtually a straight-line distillation-curve.

Detonation Characteristics of the Blends

As an indication of how these values run, one or two points are mentioned to indicate the order of magnitude of the detonation characteristics of these blends. For United States Government fighting aviation-gasoline from pure normal hydrocarbons, with an average boiling-point of 200 deg. fahr., 3 cc. of tetraethyl lead per gallon would need to be added to bring the normal hydrocarbon mixture up to straight-run Seminole Oklahoma gasoline.

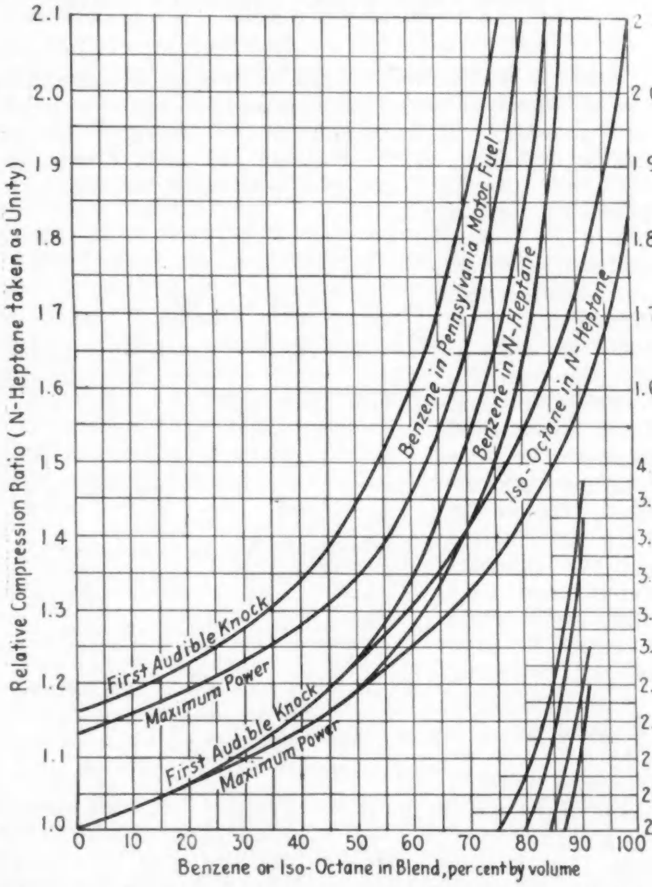

FIG. 2—RESULTS OBTAINED IN TERMS OF RELATIVE COMPRESSION-RATIO BASED ON PURE NORMAL HEPTANE

Similarly, for United States Government domestic aviation-gasoline from pure normal hydrocarbons with an average boiling-point of 230 deg. fahr., 4.1 cc. of tetraethyl lead per gallon would have to be added to the standard pure normal hydrocarbon-mixture to equal the same material from the Seminole Oklahoma gasoline.

(*Concluded on p.* 492)

Downdraft Carburetion

Discussion of E. H. Shepard's Annual Meeting Paper[1]

ACCORDING to one discusser, the boat builder found that from 200 to 225 hp. is required to obtain a speed of 40 to 45 m.p.h. with the present V-bottom 26 to 28-ft. hull, and therefore turned to the engine builder to obtain the needed additional power at an engine speed of 2000 to 2500 r.p.m. In the first attempt the engines were equipped with dual carbureters but this was found undesirable. Further experiments led to the adoption of the downdraft carbureter, and this has proved satisfactory for marine-type engines.

Another discusser states that the downdraft carbureter has not improved the mixture-preparation qualities to any great extent, and the advantage of a large manifold is questioned. The factors affecting engine power are mentioned and experiments with manifolds are cited.

The positive shut-off of gasoline and the consequent elimination of fire risks is a valuable feature of the downdraft carbureter, another advantage being that if the oil supply in an engine becomes low, immediate warning is given because the engine either would cease to function or would operate in an uncertain way.

Data on cold starting are presented, the question of horizontal versus vertical carbureters is raised and the possibility of engine stoppage during a prolonged idling period is mentioned.

In explanation of the uniform fuel-air ratio of the carbureter under discussion, it is said that because the level is above the nozzle the correct amount of fuel is supplied at the low air-flow and compensates for the deficiency of the flow from the nozzle which is experienced with a conventional carbureter.

L. H. GRISELL[2]:—Our company began experimenting with downdraft carbureters more than three years ago; duplex downdraft carbureters have been in regular production for our 200-hp. engines since December, 1927. Originally we wanted a carbureter that would be adaptable to marine use and which would provide more power per cubic inch of piston displacement, better engine accessibility and greater flexibility. After adopting this type of carbureter as standard equipment, we obtained additional desirable characteristics; these were ease of starting, better fuel economy, safety for the passengers and protection for the engine.

Development of Additional Power

After the boat builder had exhausted all his resources and found that he could not obtain the speed desired by his customers, he turned to the engine builder in search of additional power. As a result of his experimentation the boat builder found that from 200 to 225 hp. is required to obtain a speed of 40 to 45 m.p.h. with the present V-bottom 26 to 28-ft. hull. This power must be delivered in what automobile engineers probably would consider a relatively slow speed; namely, from 2000 to 2500 r.p.m. This speed range must be maintained to obtain the most efficient propeller performance.

In the first attempt to obtain additional power, the engines were equipped with dual carbureters, each carbureter supplying fuel to three cylinders. This arrangement was found to be undesirable because of the difficulty of maintaining synchronization of throttle controls at both the open and the closed position. The control-rod that linked the two carbureters together happened to be in a very accessible position, and the owners seemed to take particular delight in changing its adjustment. This in many cases resulted in very irregular operation of the engine because it seemed to be difficult for the owners to readjust the controls properly so that the engine would idle evenly on all six cylinders. This construction also interferes materially with access to the valve tappets, particularly in the L-head engine. Marine engines require a water-jacketed manifold-construction which makes them rather bulky as to over-all outside dimensions. All of this tends to crowd the lower line of the manifold down over the valve covers so that the inspection plates are rendered very inaccessible to the mechanic, particularly if the cockpit and engine-bed construction is such that it comes well up the side of the engine. It was our desire to get the carbureter well up out of the way, so that the mechanic who was attempting to adjust the tappets could do so easily.

Design Difficulties Specified

The naval architect corresponds to the artist and the body designer in the automobile field. He has been known to become so enthusiastic from reading various claims regarding the long life and durability of marine engines that he proceeds at once to order the engine and drop it into the hull as soon as the engine beds have been installed. He then sets his carpenters to work to build the boat around the engine. While this may seem to be an extreme case, many a boat has needed to have part of its superstructure and deck removed to get the engine out for its winter overhauling, because the hull exceeded the naval architect's expectations and did not spring a leak or sink during its first summer's use. Thus, the need of accessibility influenced us to place the carbureter on top of the engine.

Our next attempt was to install an inverted updraft carbureter on the top side of the manifold. This arrangement gave better full-throttle power but did not meet our requirements, because this type of carbureter lacked the required flexibility and was inclined to have certain flat spots, particularly within the part-throttle

[1] See S.A.E. JOURNAL, February, 1930, p. 153. Mr. Shepard is a member of the Society and chief engineer of the Holley Carburetor Co., Detroit.

[2] M.S.A.E.—Chief engineer, Scripps Motor Co., Detroit.

range. The Holley downdraft carbureter was used next, and it immediately met the first three requirements; namely, more power, accessibility and flexibility. My limited contact with present developments in the automotive field, obtained through the medium of trade papers, leads me to believe that the automobile engineer is now following the same process of development and research through which we passed when we first investigated the subject.

Carbureter Experiments Cited

A casual examination of recent downdraft carbureters seems to indicate that the majority are really the inversion of the updraft design and that full benefit has not been taken of the operating characteristics which are present when the jet outlet is below the fuel level in the carbureter bowl. This gravity fuel-feed to the nozzle makes it very easy to control the air-fuel ratio throughout the range of the carbureter. The ease of control under these circumstances is very readily demonstrated by some experiments which we conducted with one of the Holley carbureters.

During these experiments we decided that, since a small gravity-head is conducive to good operation, it would be possible to increase the gravity head below that which was standard with this carbureter. We made a jet having a very long tube and extended it down into the throat of the carbureter 2 in. beyond the position usually occupied by the main jet. We then changed the taper of the needle to compensate for the different operating conditions. This resulted in a carbureter which was very flexible and which developed greater power-output than did the standard carbureter. The flexibility was maintained, despite the fact that the venturi was removed from around the main jet and no provision was made to bleed air into the side of the main jet. The principle of carburetion by gravity feed to the nozzle may be objectionable for some reason with which I am not familiar, particularly when this principle is applied to the automobile carbureter. I have been using a carbureter of this type on my own car and have not discovered anything which would prove detrimental to the operation of the engine if placed in the hands of the average driver.

L. H. GRISELL

The average boat owner demands a considerable range of flexibility in his marine powerplant. He may make short turns and banks at full speed and then suddenly shut off the throttle, or he may troll for fish and let a 200-hp. engine idle for hours. Ease of starting is another requisite in the marine field. Regardless of the size of the batteries or starting motors used, cranking an engine of the 200-hp. class for a comparatively short period will render this equipment inoperative. With this type of construction, it seems that great care must be exercised to prevent flooding the engine; but the jet arrangement for starting that has been outlined in the paper will permit a very considerable amount of choking without flooding. During the time that this carbureter has been used as standard equipment on our engines, we have received no complaint from owners in regard to flooding.

Among the advantages obtained through the use of this carbureter, which we did not have in mind when originally considering its adoption, is the item of fuel economy. We recently sold to the United States Navy a number of our engines that were equipped with them. These stock-job engines were tested under Government supervision and showed an average fuel consumption of 0.53 lb. per hp-hr. at 2200 r.p.m., and no attempt was made to improve upon the fuel economy during the test.

The automobile engineer who has increased the piston displacement and horsepower of his engine to compete with the Model-A Ford car in performance possibly has found that he is not getting an increased mileage with these larger engines. We believe that, because of its extreme flexibility and ease of calibration, it would be possible to develop an automobile carbureter which would show good economy throughout the driving range.

Fire Hazard Minimized

As to the safety of the passengers, a fire hazard exists because of the possibility of backfiring of the engine in the engine compartment of the boat. While this downdraft carbureter is not particularly susceptible to backfiring, the placing of the carbureter on the top of the inlet manifold removes the backfire flame a considerable distance from any inflammable vapors that might be present in the bilge of the boat. However, to eliminate even this risk, we developed two distinct types of flame arrester which would quench the flame of backfiring; both were very compact and of simple design. Any attachment in the way of flame arresters or air-cleaners can be installed readily without causing any action detrimental to the performance of the gravity-feed-to-the-nozzle type of carbureter.

The interlinking of the carbureter and the lubricating system of the engine through the medium of the oil diaphragm has given us no trouble after the engine is delivered to the owner. We have had only one instance in which bearings were burned out since the adoption of this carbureter. In this instance the owner operated the engine despite the warning given by the failure of the carbureter to respond to the throttle. He removed the cover from the oil diaphragm and inserted a wooden block to hold the diaphragm valve open so that the engine would operate regardless of whether it had any oil pressure or not. As a result, his engine was disabled and required a complete overhaul. In event of the failure of the oil pressure, the carbureter will cut out immediately; but it is possible to operate the engine at slow speed and obtain sufficient engine speed to drive the boat to the dock, running the engine with the choke partly pulled out after the low oil-pressure has cut out the carbureter.

The carbureter described has met our requirements in every respect for marine use; namely, more power per cubic inch of piston displacement, better accessibility, greater flexibility, better fuel economy, safety for the passengers, protection for the engine and better appearance. It has recently been adopted by seven more of the leading marine-engine manufacturers. The success of the downdraft system of carburetion in the marine field is, we believe, responsible to a large extent for its adoption by some of the automobile industry companies.

Mixture-Preparation Qualities Discussed

FOREST S. BASTER[3]:—Mr. Shepard has designed a submerged needle and a baffle arranged so that the oil pressure of the engine actuates a gasoline supply-valve. Let us consider such a deviation from a sales viewpoint. If I offered to sell someone a key-winding watch that is identical with the one he carries, except for age, I would have very little chance of making a sale; but if I tried to sell a self-winding watch, my chances of a sale would be much improved. I do not mean to infer that the marine-equipment manufacturers who have almost unanimously adopted Mr. Shepard's carbureter did it solely because it is different, but I mention this to suggest what might happen to the sales of an automobile carbureter somewhat novel in design.

I admit that the passenger-car engineers have been more or less at the mercy of the carbureter organizations. Has Mr. Shepard's design sufficiently alleviated this condition? To me it has not, since I believe that his design has not in any great degree improved the mixture-preparation qualities. He has considerably reduced the minimum operating air-velocity, which fact in itself might even aggravate the mixture-atomization qualities, although it does, as Mr. Shepard indicates, permit the use of a larger manifold. Perhaps he is aware that less atomization obtains but better performance is possible through the use of the depression in the manifold at the bottom of the inverted riser. My experience indicates that this depression is very helpful; in fact, it is so effective that, with its use, satisfactory engine performance resulted even though the particular carbureter used had a jet discharge which was intermittent and much like that of an oil-can.

F. C. MOCK

Even though Mr. Shepard claims considerable advantage with a large manifold, I take exception to some degree at least. We must of necessity consider the length along with the diameter, since it performs a very important part in volumetric efficiency. For example, a very large pipe might give the maximum horsepower, while a pipe considerably smaller and having a correct length might sacrifice 5 per cent of the maximum power and yet would give a 10 to 15-per cent increase throughout the major torque-range. In connection with the downdraft carbureter, I suggest the absence of loading if the manifold is thoroughly downdraft; in other words, if the valves are reversed from the position shown in Fig. 6 of Mr. Shepard's paper[4].

M. A. TRISLER[5]:—Replying to Mr. Baster's questions as to the effect of the downdraft system on atomization and on the operation of the engine, with any downdraft carbureter the fuel drops directly on a hot-spot regardless of whether the fuel is above the nozzle or below it. With this system the heavy ends of the fuel actually are heated by this hot-spot, so it is not necessary to overheat the entire mixture supply. This in itself inherently provides better atomization for a given mixture temperature and manifold depression.

A test made on a 100-b-hp. automobile engine in a cold room at —10 deg. fahr. showed that the starting ability compared very favorably with that for any other known type of carbureter. I believe that this carbureter would be particularly well adapted to use heavy fuel in a large engine with a suitable vaporizer.

Factors Affecting Engine Power

M. E. CHANDLER[6]:—With our present type of automobile engine, the carbureter meters the fuel, the manifold partly vaporizes and distributes it, and the cylinder completes the vaporization and burns it. Of the three, the manifold is the least efficient. It distributes air and vapor very well, but distributes liquid fuel very poorly, especially at low velocities; therefore we add heat to the manifold to increase vaporization and to aid distribution.

The power of a given engine is affected, among other things, by the capacity of the carbureter, the capacity of the manifold, the distribution and the temperature of the mixture. We have found in numerous instances that, with the downdraft system of carburetion, one or more of these factors can be altered so as to give increased power, smoother operation, easier starting and quicker warming-up. In experimenting with the inlet manifold, we have found it very helpful to design a purely experimental manifold that can be altered in a few minutes as regards shape and areas, and we believe that such a manifold should be built for every new engine development.

Experiments with Manifolds Cited

F. C. MOCK[7]:—The first float-feed carbureter was made by William Maybach, who died several months ago. Previously, in the tricycles and buggies with which attempts were made to operate on gasoline, the internal-combustion engines were fed with a mixture produced either by bubbling air through the tank or sucking it past a wick partly submerged in the gasoline in the tank. The mixture strength obtained depended upon the velocity of the air, the temperature of the atmosphere, the depth of gasoline in the tank and several other factors. Mr. Maybach conceived the idea of the float-feed spray-jet carbureter, and this has made possible our present use of automobiles. It is interesting that, in his first patented conception of this kind of carbureter, he showed an updraft carbureter, a down-turned carbureter, a hot floor for the inlet passage and an exhaust-jacketed intake. This, I believe, was in 1889.

In the right-hand view shown in Fig. 6 of Mr. Shepard's paper[8], a downdraft passage and a following updraft passage are shown, both providing the same air velocity. Several years ago we experimented with wood and glass models of manifolds. We found that just as much difficulty was experienced in raising the fuel from the bottom of the horizontal run of the riser up to the valve as was found anywhere else in the inlet system. If we imagine that this valve is turned around as though it were in a valve-in-head engine, with the fuel feeding downward from the horizontal lead of the manifold, it might seem that the problems were solved; but those who have dealt with constructions of that sort will agree that this would result in what we call a

[3] In charge of six-cylinder design room, Hupp Motor Car Corp., Detroit.
[4] See S.A.E. JOURNAL, February, 1930, p. 155.
[5] Jun. S.A.E.—Engineer, Holley Carburetor Co., Detroit.
[6] M.S.A.E.—Engineer, Stromberg Motor Devices Co., Chicago.
[7] M.S.A.E.—Engineer, Bendix Aviation Corp., South Bend, Ind.
[8] See S.A.E. JOURNAL, February, 1930, p. 155.

"sloppy" engine, that is, one that would not run smoothly under changes of throttle and speed. The reason is that, if we rely on a low velocity of air to sweep fuel along a flat passage, the engine does not run steadily because there are small waves on the surface of the liquid as it trickles along, and when we consider that one separate fuel-charge represents about one-third the volume of the rubber eraser on the end of a lead pencil, we can readily understand that these waves as they sweep in do not give definite and accurate charge-measurements.

What I am leading toward is that I do not believe that the mere adoption of a downdraft, or horizontal and downdraft, fuel-feed releases us from limitations of evaporation, nor will it release us entirely from the limitations of velocity that we have heretofore had to accept with the updraft carbureter. There is no question, however, that the downdraft construction is of assistance under some conditions, and it is advantageous for many reasons; but I think that all who work with carbureters will agree that we must still have sufficient velocity and heat.

Heating Airstream Decreases Volumetric Efficiency

T. J. Lítle, Jr.[9]:—Regarding the degree of heat on the manifold, mentioned by Mr. Mock, I think that Mr. Shepard stated in his paper that less heat would be required in that particular installation than if it were supplied and applied to a branch of the carbureter and completely surrounded the inlet passage. In other words, it seems to be adequate to provide a hot-spot but not necessary to heat the branch, which, incidentally, would heat the airstream and thus decrease the volumetric efficiency. I think it is conceded that no more heat should be used than is necessary to provide adequate functioning in a particular case.

T. J. Lítle, Jr.

It has already been said that no heat is required in certain cases, and this is the most revolutionary of any discussion thus far submitted, because we have all been thinking that a great amount of heat in the manifold was needed to cause the engine to operate satisfactorily. In fact, with a high carbureter-level or with the gasoline level higher than the orifice through which it emerges, no energy is required to pull fuel up the tube, as the fuel is already there to meet the demands of the engine. If we imagine a bubble of fuel resting on top of the orifice and merely being picked off without effort and dragged down into the airstream, that is the combination which we are discussing. Therefore, why expend energy merely to elevate gasoline to the nozzle and thus penalize the high-speed operation of the engine? Why provide much more atmospheric compression in the inlet manifold than is really necessary? We have decreased the necessity for using vacuum for that particular purpose and have increased the volumetric efficiency possible for that engine as much as 13 to 14 per cent.

We have heard that we might increase the power of a given engine from 7 to 15 per cent by using cold carburetion, and in addition we have about a similar possibility of increasing the power if the fuel level is elevated so as not to require so much energy to pull the gasoline up to that point. The provision made to cut off the gasoline supply if the engine should stop becomes a necessity with this construction, in which the fuel level is above the orifice; but, incidentally, that constitutes a very valuable feature.

Advantages of High Fuel-Level

In marine work, the bane of existence of the boat owner is the accumulation of gasoline in the bilge of the boat. That possibility exists in the case of carbureters of the updraft type, and some positive means for preventing gasoline from seeping from a nozzle or from a flooded carbureter into the bottom of the boat or the pan of the engine is a necessity. The positive shut-off of gasoline and the consequent elimination of fire risks is one of the most valuable features of the downdraft carbureter, according to the underwriters.

A second advantage incidental to this construction is that, if the oil supply in an engine should become low, immediate warning would be given because the engine would cease to function or would operate in an uncertain way that would necessitate pulling out the choke somewhat to enable the operator to get to an oil-supply station for replenishment. Many an engine has been burned out because the oil ran through without the knowledge of the operator. He does not watch the oil gage continuously, but only occasionally; therefore, positive warning of a low oil-supply is a great benefit. In fact, a carbureter having the fuel level somewhat above the nozzle functions much better throughout the range than does one in which the fuel must be lifted to a considerable extent.

I have an engine that functions with remarkable smoothness and shows no tendency toward leanness throughout the carbureter range; rather, the carbureter follows the demand of the engine straight through the entire range. The early engines were built so that the fuel level was high. In the first Cadillac engine, the fuel level above the nozzle was high and, when the engine stopped, the fuel was automatically cut off by a diaphragm or disc which was simply floating in the airstream in the manifold. Although it is true that the engine had only one cylinder, the correct functioning of the carbureter was very marked. I owned one of those cars and tried out another type of carbureter, but found that the carbureter substituted did not work as well as the one that was originally installed. This probably proved that the improved operation throughout the range was due to the high fuel-level.

Charles A. Winslow[10]:—Our company also has had some experience with a manifold of the type shown in Fig. 6 of Mr. Shepard's paper[11]. I agree with Mr. Mock that some heat and a provision for the prevention of puddling is necessary; in fact, we provided a flat hot-spot directly below the riser which was higher than the valve ports. We gave this a gradual down-drain and, as it was lying on the hot-spot and the valve port was below, it actually prevented the puddling that Mr. Mock mentions. We have had very good results with

[9] M.S.A.E.—Director of engineering, Holley Carburetor Co., Detroit.

[10] M.S.A.E.—Development engineer, Hercules Motors Corp., Canton, Ohio.

[11] See S.A.E. Journal, February, 1930, p. 155.

this type of manifold, as compared with a first-class updraft manifold.

Data on Cold Starting Presented

W. C. BAUER[12]:—Are any data available on cold starting at 20 deg. fahr. or at lower temperatures?

T. S. KEMBLE[13]:—In connection with an L-head engine, I built a dual manifold several years ago in which a very small manifold was located inside the larger manifold and served perfectly for starting and idling so long as the temperature was not too low. It operated so well that it was impossible to crank the engine so slowly by hand that it would not start the first time the mixture was compressed, ready for ignition. But with that same equipment at a temperature of 5 deg. fahr. below zero several starter batteries were run down in an attempt to start the engine and the only result was a trickle of gasoline out of the carbureter air-intake. In this case, the gasoline-air mixture was carried right to the valve pockets, but the gasoline separated from the air and came back through the main manifold and carbureter. That experience indicates to me that considerable ingenuity may still be required before even downdraft induction-systems can be made to function perfectly with L-head engines under extreme cold-weather starting conditions.

E. H. SHEPARD

Horizontal versus Vertical Carbureters

R. W. A. BREWER[14]:—Why is it that horizontal carbureters are not received with favor in America?

MR. MOCK:—When the horizontal carbureters were used, about 1916, we thought that a water-jacket provided enough heat to the manifold. The carbureters were applied on the side of the engine opposite to the valves where there was plenty of room to install them between the engine and the hood. Since we have used hot-spots, with intake manifolds on the valve side of the engine, there is not room enough to install a horizontal carbureter. We always thought that the horizontal manifold worked as well as the vertical carbureter having equivalent manifolding.

MR. LITLE:—Answering Mr. Brewer, any carbureter company will supply a horizontal carbureter if provision is made on the engine for its installation.

L. K. SNELL[15]:—It seems to me that the removal of the venturi from the downdraft carbureter described is a good illustration that all carbureters are alike at high speed and high load. It would be interesting to analyze curves of power efficiency and the like throughout the varying range of speeds and loads.

H. CAMINEZ[16]:—Is the carbureter described by Mr. Shepard the only one in which the jet is below the float level? Is the increased performance described due to the fact that the jet is below the float level or because it is a downdraft carbureter?

MR. TRISLER:—I believe this is the only carbureter that maintains the fuel level above the nozzle discharge. The increased performance is due to the combination of a gravity-fed nozzle and a downdraft carbureter. The favorable results obtained are due to the fact that the gravity-fed nozzle enables the carbureter designer to take full advantage of the down-draft design to secure maximum power without sacrificing flexibility.

Engine Stoppage During Idling Discussed

REX C. DARNELL[17]:—Under idling conditions, with hot oil on seven-bearing and on nine-bearing engines, difficulties are experienced in registering pressure on the gage. I have had considerable difficulty in trying to bolster up that pressure. The paper indicates that the diaphragm cuts off the fuel at oil pressures of 10 lb. per sq. in. or less. Will there be any difficulty during a prolonged idling period of the engine in that it will stop because the diaphragm shuts off the fuel? I can conceive of hazardous conditions that might be brought about by such a contingency.

MR. TRISLER:—The figure of 10 lb. per sq. in. as stated, at which the diaphragm shuts off, was used only in experimental marine carbureters. We have since devised a means much more sensitive in which the diaphragm will open at ½ lb. per sq. in. This sensitive diaphragm was designed primarily for use on automobile carbureters, and either oil-pressure or gasoline-pump pressure can be used to actuate it.

S. M. UDALE[18]:—To overcome the difficulty caused by low pressure we fit a check-valve in the outlet from the oil-pump and connect the diaphragm directly with the oil-pump. This check-valve does not restrict the flow appreciably and no objection has been found to its use.

A. P. BRUSH[19]:—Concerning the modern downdraft carbureter, if fuel head is desirable on jet orifices, and with mechanically driven modern fuel-pumps that are calibrated for a given fuel pressure, I am beginning to wonder why the fuel chamber and float mechanism are needed.

MR. LITLE:—That is an expected development and it is likely that all the companies are working along that line at present. Emphasis should be given the fact that it is considered good practice, which is borne out by testing experience, to use these high levels because no particular effort is needed and other factors are not being disturbed by merely dragging the fuel off the jet or raising the fuel to the nozzle.

There is no disposition on the part of the manufacturer of this particular carbureter to force it on the market before very careful research work now being done is completed, so far as passenger-cars are concerned. The marine type has been perfected.

MR. TRISLER:—We have found that a ½-in. head above the nozzle, that is, a level ½ in. above the orifice outlet in the venturi, provides the best curve for automotive engines. It would be very difficult to maintain the output pressure of a pump within the limits at which the float in the carbureter maintains this head on the nozzle.

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[12] Fuel and lubrication section, Standard Oil Development Co. Research Laboratories, Linden, N. J.

[13] M.S.A.E.—Consulting engineer, St. Louis.

[14] M.S.A.E.—Consulting engineer, Aircraft Engine & Accessory Development Corp., Jenkintown, Pa.

[15] M.S.A.E.—Eaton Axle & Spring Co., Cleveland.

[16] M.S.A.E.—Engineer in charge, aircraft engine division, Cadillac Motor Car Co., Detroit.

[17] M.S.A.E.—Chief engineer, Taylor Bros. Mfg. Corp., Elkhart, Ind.

[18] Engineer, Holley Carburetor Co., Detroit.

[19] M.S.A.E.—President, Brush Engineering Association, Detroit.

Maintenance of Uniform Fuel-Air Ratio

MR. LITLE:—When the fuel enters the combustion-chamber it is vaporized, but very little vaporization takes place in the inlet manifold or in the carbureter. The vaporization begins when the mixture enters the combustion-chamber in and around the hot valves and mixes with a residual charge from the last explosion, and is completed on the reflex stroke.

Will Mr. Trisler explain the remarkably uniform ratio maintained between the fuel and air?

MR. TRISLER:—The level being above the nozzle supplies the correct amount of fuel at the low air-flow and compensates for the deficiency of flow from the nozzle which is experienced with a conventional carbureter. Throughout the remainder of the range, it is easy to maintain a correct fuel-air ratio by regulating the fuel with different amounts of air-flow as determined by the throttle.

MR. BREWER:—The dribbling-jet system seems very similar in its characteristics to the jets of the Bavary system; that is, constant flow under gravity plus the flow due to the induced suction. In both cases, there is a combination of the two methods. Apparently the horizontal and the downdraft carbureters have the same characteristics and the fuel does not need to be lifted. Why is one system better than the other?

MR. TRISLER:—Theoretically, the carbureter under consideration would give the same results as would the device originally conceived by Bavary; but, as stated in the paper, when a point is reached at low speed at which the air does not bubble through the fuel, the Bavary system assumes the characteristics of an ordinary nozzle and ceases to give a flow of fuel into the air-stream below a certain critical air-flow figure which usually is well within the low-speed end of the driving range. The curves shown in Mr. Shepard's paper are representative of the characteristics of an air-bled or Bavary nozzle. After the air-flow through the carbureter is reduced to a certain point, there is not sufficient suction on the nozzle to bubble air through the fuel; therefore no fuel flows from the nozzle. I see no reason why horizontal carbureters cannot be used in this connection just as well as can the downdraft carbureters.

MR. BREWER:—The air-bled feature is not what I imply. I refer to the feature of two sources of fuel-flow, one under gravity and one under induced head.

HAROLD F. BLANCHARD[20]:—What is the size of the engine on which experiments were made with this downdraft carbureter?

MR. TRISLER:—It is a 200-hp., 677-cu. in. marine-engine.

MR. BLANCHARD:—What is the actual loss of energy in lifting fuel on an updraft carbureter?

MR. TRISLER:—We have no data on that point. When using a larger venturi, which is possible when maintaining the fuel level above the nozzle in this type of carbureter, the need for a high air-velocity is avoided, and this is evident in the low manifold depression which results in an increase in the volumetric efficiency and in the power developed.

[20] M.S.A.E.—Technical editor, *Motor Magazine*, New York City.

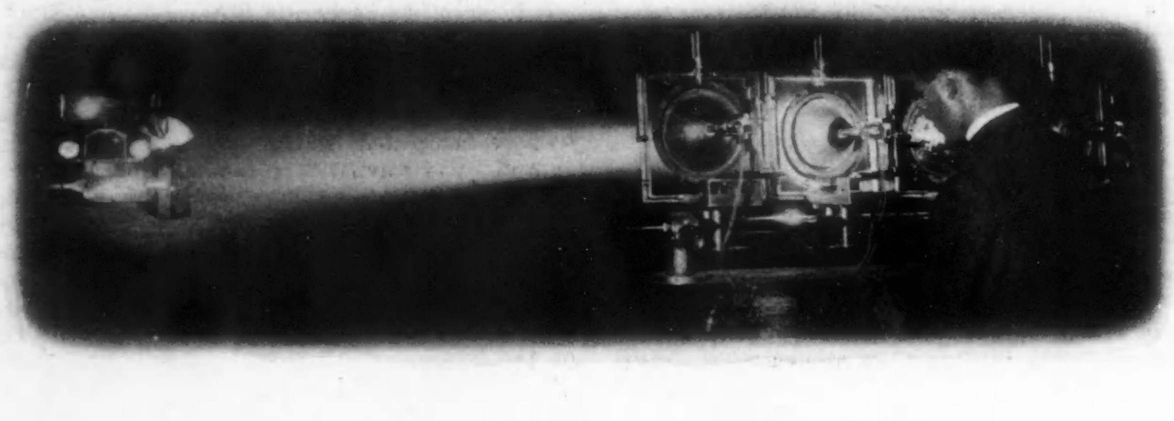
Detonation Characteristics

(*Concluded from p.* 486)

For United States Government motor gasoline from pure normal hydrocarbons with an average boiling-point of 260 deg. fahr., the addition of 4.5 cc. of tetraethyl lead per gallon would be required.

This report is only preliminary. We need more refined equipment, and the data are given only as a possible indication of what might be expected. These are results on pure normal hydrocarbons. Perhaps we should continue our study, on to the mixtures of pure naphthene hydrocarbons along this series or possibly some other similar mixture as Mr. Boyd has suggested, and possibly to a mixture of two groups, so that we might have detonation characteristics practically identical with those of the material we want without having to add a knock-inducing agent like normal heptane or a knock-suppressing agent such as tetraethyl lead.

Undoubtedly, any standard fuel that might be regarded as desirable for use should be evaluated for detonation characteristics at temperatures such as 150, 200, 250, 300 and 350 deg. fahr. so that its basic characteristics could be accurately known. Then such a standard fuel would be suitable for reference for fuels used in low-temperature and high-temperature liquid-cooling and in air-cooling systems.



Production Standards Applied to Motor-Vehicle Maintenance

By H. B. Hewitt[1]

Transportation Meeting Paper — *Illustrated with* Charts and Photographs

MAINTENANCE is a part of automotive production and as such is destined to adopt production standards. While passenger-car manufacturers have fostered the application of these standards to maintain a parity between factory production and maintenance, commercial-vehicle operators have established standards and methods in response to an economic demand to obtain low-cost maintenance. How this has been done in Philadelphia is the subject of the paper.

Scheduling vehicles through the shop in accordance with the seasonal requirements of transportation enables a centralized shop having 120,000 sq. ft. of floor space to service a fleet of 450 motorcoaches, 1500 taxicabs and approximately 150 pieces of various utility equipment with practically no fluctuations in the working force and the minimum number of spare units. Major overhauling of motorcoaches is done in the winter months when the demand is relatively light, while the taxicabs receive attention in the summer. As the demand for both classes of vehicle is greatest over week-ends, the main shop and the eight operating garages where scheduled repairs are handled have a five-day week, which enables 100 per cent of the vehicles to be in service on Saturdays and Sundays. In addition to scheduled repairs and progressive maintenance, constructive maintenance is handled on the basis of how much can be done to prolong vehicle life and encourage the riding habit. Numerous examples of what has been done along this line and descriptions of repair methods are included.

The provision of adequate tools and shop equipment is emphasized as the most remunerative application of production standards to maintenance. In this connection, the soldering of commutators, the use of a specially designed universal hoist, moving chassis along production lines by a power broom that also cleans the shop, cutting off screw heads to facilitate the removal of molding and panels, and spraying paint are some of the examples cited of the time and labor savings effected.

Preparation of a standard-practice manual that includes all subjects pertaining to maintenance and garage and shop procedure is described. Such a manual serves as a basis for determining the proper execution of repairs and saves time for executives and engineers by eliminating hours of individual instruction and numerous group meetings.

Increasing the life of low-mileage units to secure a properly balanced vehicle is one of the most difficult problems that the maintenance engineer has to solve. To aid in this work, comparative charts are issued every four weeks to reveal the weaknesses in maintenance and equipment. In this way effort can be concentrated on the vehicle parts or units that require attention most frequently.

Points brought out in the discussion at the meeting relate to tire maintenance, payment of the mechanics on the piecework basis and the use of reclaimed oil. In a written discussion submitted after the meeting, R. E. Plimpton states how far the methods outlined in the paper can be applied by three different groups of operators and emphasizes the advantage of making unit repairs at such time as the performance of the vehicle may indicate to be desirable rather than rebuilding the complete vehicle at definite time or mileage intervals.

THE application of production standards to motor-vehicle maintenance is so comprehensive and general and involves the opinions and experiences of so many men interested in motor-vehicle maintenance and manufacture that I hope only to express my own conceptions and refer to my own experiences in regard to it, confining these chiefly to commercial-transportation vehicles. I feel that the subject should be of concern to manufacturers as well as operating men. On account of the relatively large production and highly developed standards and methods of manufacture in passenger-car organizations these represent the real places to observe and study production standards.

Maintenance is a part of automotive production. As such it necessarily follows original manufacture and is destined to adopt production standards. In the passenger-car field the acceptance of new and better vehicles has always been augmented by the lack of good maintenance. New-car sales are stimulated by new-car competition; they will continue largely on the economic basis of used-car replacements. The mortality rate per mile of motor-vehicles has been higher in the past than it probably will be in the future. This, of course, is partly due to improvements in design but will be more dependent upon improvements in maintenance.

Relation of Maintenance to Production

Approximately 135 different makes of passenger-car were sold in 1914 and only 45 in 1929, with a corresponding reduction in number of models in the same period. The production of passenger-cars in 1914 was approximately 500,000, and in 1928 approximately 4,000,000. The change from a large number of manufacturers producing small quantities to a small number of manufacturers producing large quantities is the result of the adoption of American standards in the production of a commodity in relatively large demand. Centralization of specialized efforts to produce one essentially composite

[1] Engineering assistant to vice-president in charge of operation, Mitten Management, Philadelphia.

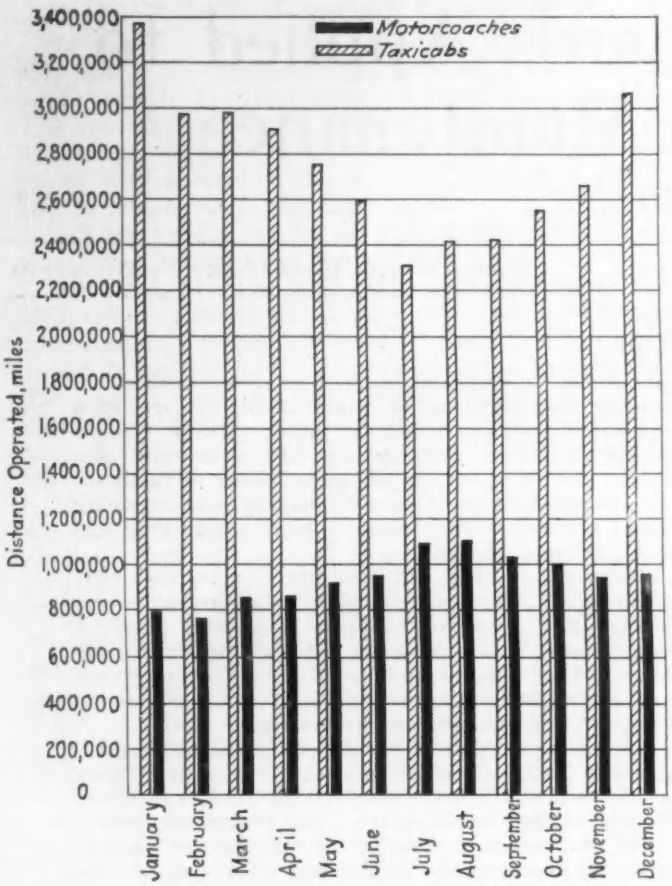


FIG. 1—CHART OF COMPARATIVE OPERATING MILEAGE OF MOTORCOACHES AND TAXICABS IN PHILADELPHIA

Major Overhauls Are Scheduled for the Periods When the Demand Is Relatively Light. Thus Motorcoaches Receive Attention in the Winter, While the Taxicabs Go through the Shop in the Summer

article has resulted in rapid development of the product, a high degree of productive efficiency and economy and stability of the industry; all of which could not have been attained by a wider distribution of competitive efforts. Approximately 100,000 service stations or repair shops are operated in the United States, or 1 for every 250 cars. This is not to be regarded as excessive but, rather, insufficient, in view of the wide distribution required to serve the thinly populated areas of the Country.

The financial volume of maintenance business is now greater than the volume of new-car sales. In this respect maintenance is in competition with manufacturing, although it may be considered a cooperative competition, for without adequate maintenance the motor-vehicle would lose much of its economic value. To follow production standards, maintenance business must centralize its efforts, improve its product and obtain the same high degree of productive efficiency and economy that has been attained in motor-vehicle manufacture. This does not call for a reduction in number of outlets, as was the case in the manufacturing field, but for an increase in volume of business and a corresponding increase in size of service stations. The increase in volume of better-maintenance business is potential. In the passenger-car field it has been partly supplanted by new-car sales, although a decrease in car sales should not be anticipated with better and bigger maintenance business. The increase in size of service stations is contingent upon executive foresight to adopt production standards, with the result that small shops cannot exist. Maintenance business should thus establish itself on a fundamentally sound basis and add stability to the automotive industry as a whole.

These comments refer particularly to the passenger-car field. In 1928 production of motor-trucks was approximately 500,000 of about 90 different makes and many different models. The number of motorcoaches built was less than 10,000 of approximately 30 different makes and numerous models. The comparatively small production of trucks and motorcoaches and the numerous makes and models indicate a condition of production similar to that existing in the early period of passenger-car development. The object of this paper is not to comment on the future evolution of truck or motorcoach production, but these statistics cannot be passed over without the economic need of a change to some centralization of efforts being apparent.

The application of production standards to passenger-car maintenance has been fostered by the car manufacturer. This policy represents the foresight of manufacturers to establish maintenance on a par with factory production. In the maintenance of commercial-transportation vehicles, the standards and methods have been established by the operator in response to the economic demand to obtain low-cost maintenance, the total of which represents a larger portion of operating expense than is the case in the passenger-car field. The difference in production and maintenance-cost proportions is even more favorable to the application of production methods and standards to maintenance of transportation motor-vehicles than to the original manufacturer of the same vehicles. For example, every motorcoach engine built by the manufacturer is rebuilt many times during its operating life.

Since we are interested particularly in motor-vehicles for commercial transportation, the following comments will be confined to this phase of maintenance. Standardization of operating equipment reflects a saving in every department, as compared with operation that includes a variety of types and makes of vehicle.

Centralized Shop Serves 2100 Vehicles

In Philadelphia an automotive repair-shop having a ground area of 10 acres and a ground-floor area under roof of approximately 120,000 sq. ft. has been established. This shop services a fleet of 450 motorcoaches, 1500 taxicabs and approximately 150 pieces of varied-utility equipment, totalling 2100 automotive vehicles. Repair work, construction work and experimental work are scheduled through this shop on a program that provides for uniform flowing in of material and flowing out of completed work. All motorcoaches are gasoline-electric, and 200 of these are of the double-deck type.

The coordination of all of the various types of transportation serving a community results in many advantages and economies to the system as a whole. In the automotive departments the scheduling of vehicles through a general automotive shop according to the seasonable requirements of transportation results in establishing the force of workmen with practically no fluctuation in numbers and permits the operation of vehicles with the minimum number of spare units.

Fig. 1 shows the seasonal mileage by months of taxi-

cabs and motorcoaches in Philadelphia. This indicates that the greatest demand for the latter is in the summer and for cabs in the winter months. Therefore, the shop program is arranged so that the major overhauling of motorcoaches is scheduled for the winter months and of cabs for the summer months. The shop hours are also arranged to accommodate the weekly demands of transportation, in that the peak demand for taxicabs in the winter is over week-ends, which also applies to motorcoaches in the summer. Therefore, the general shop is open only five days per week, permitting the maximum number of vehicles to be in service over the week-ends. This also applies to garages, which are placed on a schedule that permits 100 per cent of the vehicles to be available for service on Saturdays and Sundays. In the case of one motorcoach garage, the demand for vehicles was so great that all scheduled mechanical work is done between the hours of 1 and 8 a.m., so as to have 100 per cent of the vehicles available for service during the daylight hours. For this garage to be completely emptied of vehicles during that part of the day is a common occurrence.

The basis of all scheduled motorcoach repairs is kilowatt-hours as measured by a kilowatt-hour meter installed on each vehicle. In taxicabs and vehicles other than the gasoline-electric, the basis is vehicle miles. Fig. 2 gives a partial interior view of the central shop, in which the vehicles are lined up and pass through progressively, similar to production practice in manufacturing.

Preventive maintenance or scheduled repairing is taken care of in eight operating garages. The term "scheduled repairs" has effectively replaced the term "scheduled inspection." The significance is apparent. Replacement maintenance consists in replacing worn, damaged or defective parts. Generally these parts are replaced by new ones obtained from the original manufacturer. In many cases replacement maintenance is inadequate, owing either to original weakness or increased demand. Constructive maintenance is employed in such cases. Progressive changes may involve all vehicles, in which case the change may be completely carried out in a short period or effected the first time a vehicle is in the shop for general overhaul.

Constructive Maintenance Improves Vehicles

Constructive maintenance may be regarded as that which effects a radical improvement in design. Many changes of this kind have been found necessary to meet the change in service demands since the equipment was purchased. The result is better operation and better equipment after five-years' service than when the vehicles were first put in operation. Some of the most noticeable improvements of this type consist of the installation of pneumatic tires on double-deck motorcoaches, involving a change in wheelhousing and seating arrangement. Inclosure of the upper-deck roof has materially increased revenue, particularly in cold and damp weather. Elimination of the rear door, except for emergency use, and adoption of one-man operation represent a saving in operating labor of almost 50 per cent. Changes have been made in the engine to increase the power, decrease fuel and oil consumption and improve reliability. The completed motorcoach, as it leaves the shop, is not a repaired vehicle but one that has been remanufactured on a production basis to compete with new vehicles of the latest standards. It is not a case of doing only enough maintenance to satisfy operating demand but how much can be invested to earn a greater return by prolonging vehicle life and encouraging the

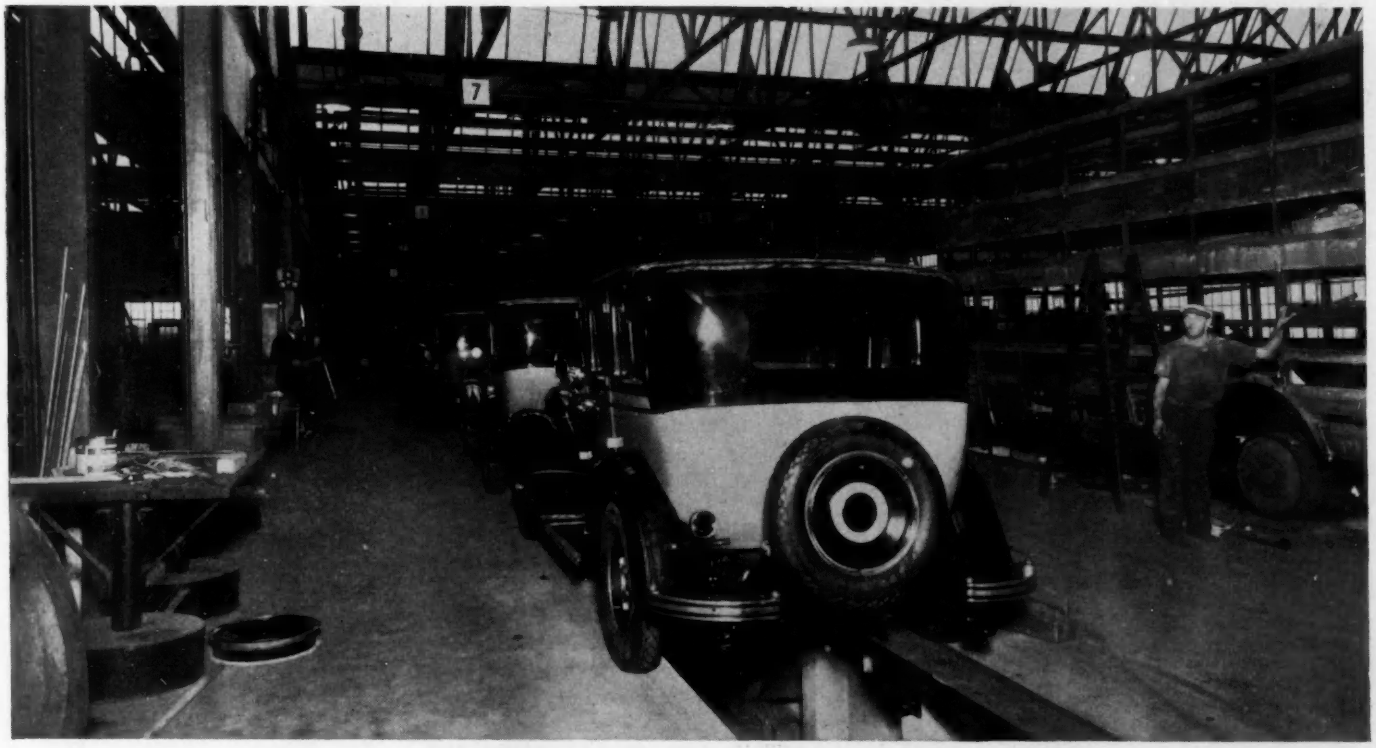


FIG. 2—PARTIAL VIEW OF THE INTERIOR OF A CENTRALIZED REPAIRSHOP

This Shop Operates on a Five-Day Week To Provide the Maximum Number of Vehicles for Service over Week-Ends. The Taxicabs and Motorcoaches Are Lined Up and Pass through the Shop Progressively, Similar to Production Practice in Manufacturing

riding habit. This progressive aspect toward maintenance has more than doubled the economic life of the motorcoach and has overcome the threat of early obsolescence.

An engineering and a drafting department are essential requirements in carrying on constructive and progressive maintenance. Their part is to design and prepare drawings for manufacturing and for shop reference. A testing laboratory and its personnel are required for the purpose of investigating new developments and designs before they are applied to operating equipment. New requirements and demands are continually arising in operation and call for a careful study to find the right solutions. These problems are entertained by the testing personnel and the engineering department.

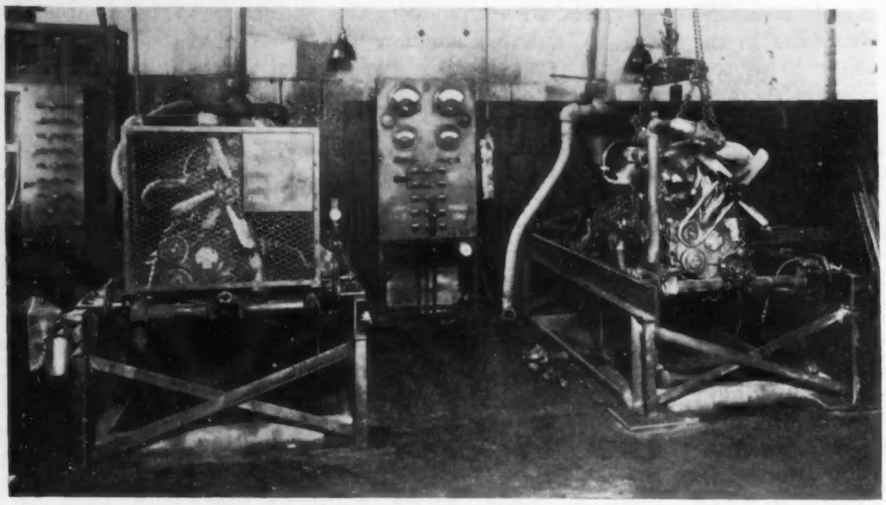


FIG. 3—ENGINE-TESTING EQUIPMENT
Engines Are Completely Rebuilt after an Average of 90,000 Miles of Operation, Except for Accidents, and Are Tested for Performance and Reliability before Being Released for Service

Labor is the primary and, undoubtedly, most important factor in either production or maintenance. Men who are skilled in the operation of machine-tools and shop equipment are usually available in large industrial centers. They require only a short period of instruction to become proficient in the repetition work to which they may be assigned. These men can be employed to meet fluctuations in labor demand. High labor-turnover and fluctuations in labor demand are undesirable in establishing production standards.

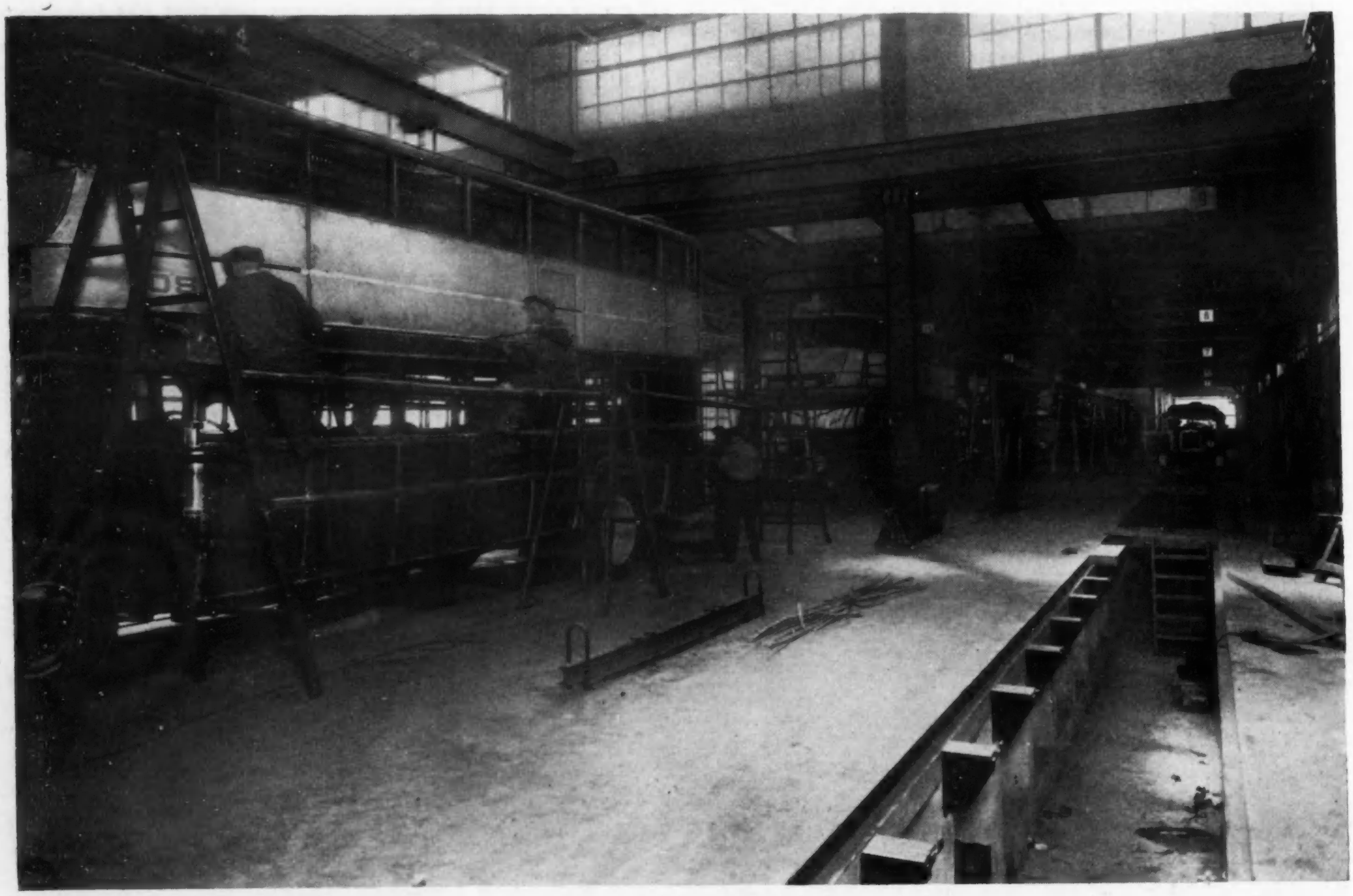


FIG. 4—PROGRESSIVE GENERAL-OVERHAUL LINE
When Received at the Shop, Motorcoaches Are Washed with Water and Steam and the Major Units Removed. Next the Body Panels Are Stripped, Sash Removed, Flooring Repaired and Other Necessary Replacement and Constructive Changes Made. As the Vehicle Travels Farther along the Line, the Major Units Are Reinstalled and the Assembled Motorcoach Is Delivered to the Paint Shop

They can be partly curtailed by careful selection and retention of desirable employes and by regulation of work in the shop, using constructive-maintenance work as the elastic medium to allow for accident work.

The performance of specialized work requires specialized supervision. This is provided by foremen in each garage and in each shop department. The shop foremen receive instructions from and report directly to the shop superintendent. Inspectors in the various departments assist in determining the procedure for repairs and see that all parts and assemblies are built to specifications. In accordance with production standards, inspectors are not responsible to the foreman on matters of rejection.

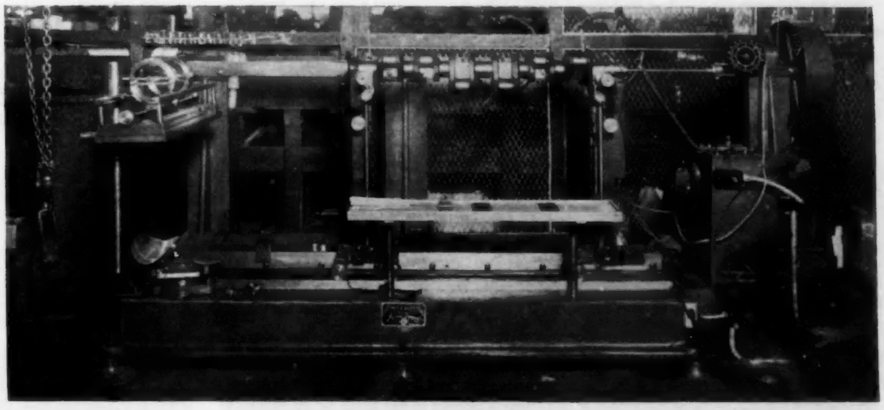


FIG. 6—DYNAMIC-BALANCING M. HINE
This Machine Is Shown Balancing a Crankshaft but It Can also Be Employed for the Armatures of Generators and Motors

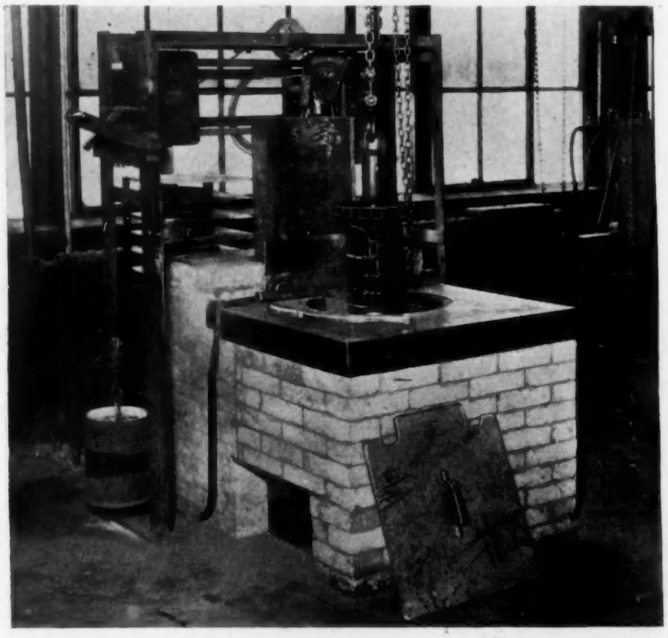


FIG. 5—ELECTRIC SOLDERING-POT
This Device, Which Uses Standard Immersion-Heaters and Controls Has Saved 1½ to 2½ Hr. per Commutator in Armature Repairs, the Actual Time the Tin Is in Contact with the Commutator Varying from 3 to 5 Min. According to the Size of the Commutator

Electrical Equipment Repairs

Progressive production routine is carried out in the electrical department. All motors and generators sent to the shop are accompanied by a card record showing the number of the motorcoach from which the unit was taken, the time the unit has been in service, the total kilowatt-hours consumed and remarks on the failure or condition. Upon receipt of this unit in the electrical department, a shop-record card is filled out to indicate its condition and the necessary repairs to be made. The unit is then taken apart and the segregated parts directed to respective sections in the department for repairs. Bearing heads, coupling flanges and miscellaneous parts are sent to the washing machines, after which they are reconditioned at a work-bench specifically assigned to repairs of each class of parts. A section is provided for the repairing of brush riggings, one for field coils, another for commutators and so forth.

All ball-bearings are accumulated and thoroughly cleaned and inspected and all that do not come within the S.A.E. tolerances except for a small additional radial-looseness are rejected. Cone concentricity is essential to smooth operation and perfect commutation, particularly on the motors, the speed of which reaches 4000 r.p.m. at the maximum vehicle-speed. Bearing-cone concentricity is necessary to obtain correct dynamic balance. For this reason new bearings are purchased under a specification permitting not more than 0.0002-in. cone eccentricity.

Motor and generator frames and armatures are moved from one operation to the next by a monorail.

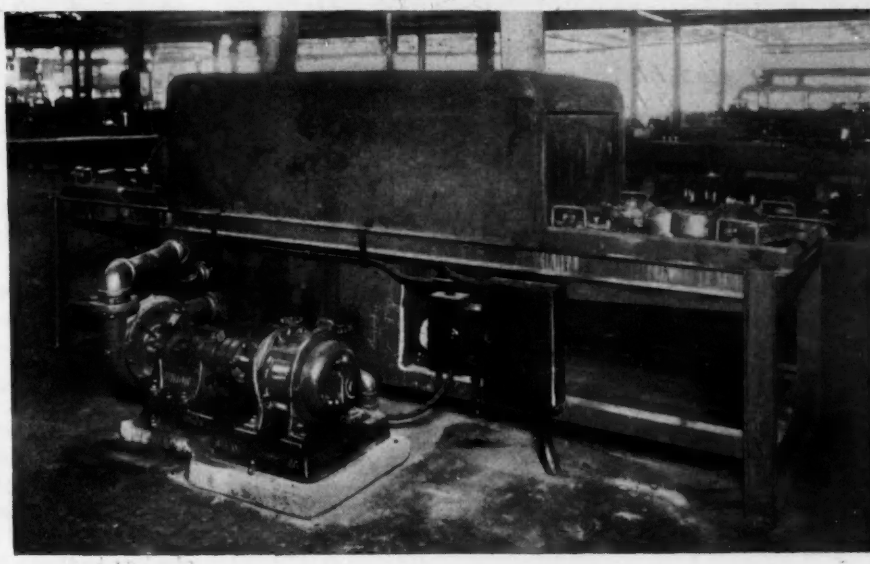


FIG. 7—WASHING MACHINE
Typical Parts Handled Can Be Seen on the Table at the Right

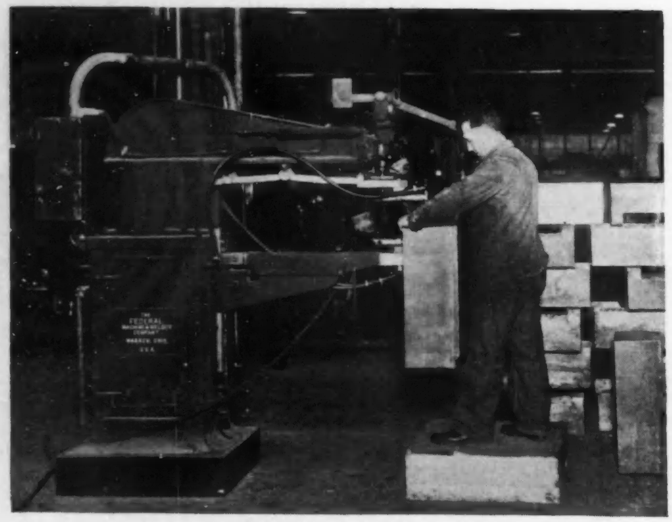


FIG. 8—ELECTRIC SPOT-WELDING MACHINE

Along this progressive line frame assemblies are cleaned and dismantled if necessary. Armatures are cleaned and stripped as required. The shaft bearing-surfaces are inspected and diameters checked with a micrometer gage. If these are undersize, the armature is directed to the welding department, where the shaft is built up and then sent to the machine-shop to be turned and ground. This is to ensure correct ball-bearing fit on the shaft at the final assembly. Commutators are examined and repaired as needed. Armatures that are to be rewound are sidetracked for this operation, after which they are placed in line for the baking and varnish treatment. The banding machine, electric soldering-pot and commutator-tightening press are arranged under the monorail in the order in which they are used. After the baking treatment, completed armatures proceed to the commutator turning and undercutting machine. From there they proceed to the final assembly,

FIG. 9—BRINELL-TESTING THE HARDNESS OF A SHAFT
A Scleroscope, Which Is also Used, Is Shown on the Bench

where all other assembly parts are accumulated after being reconditioned at their respective sections.

After units are completely assembled they are given a running test under full load and maximum operating-speed. Performance to exacting standards on this test is required before the units are sent to the storeroom to be issued to garages as needed for unit replacement. The test includes high-potential and megohm-ground insulation test. In reconditioning power units, many changes are effected to improve their construction and operation. The rebuilt unit is better and has more miles of life in it after five-years' operation than when

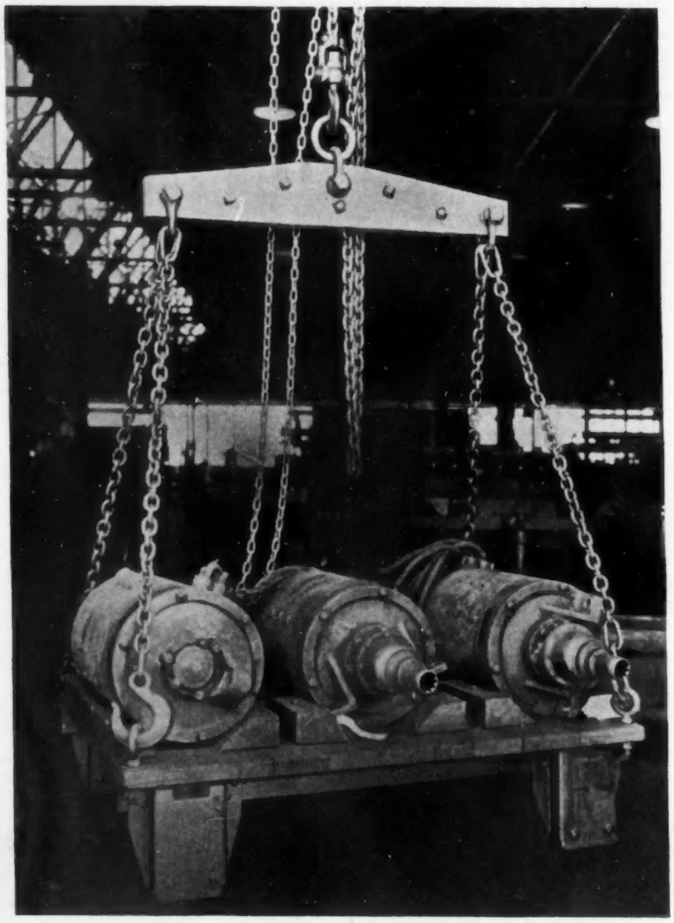


FIG. 10—SPECIALLY DESIGNED UNIVERSAL HOIST
This Facilitates the Handling of Large Units in the Garages and Shop. The Platforms Can also Be Moved by a Lift-Truck

it was first put in service. As an example, the miles per road failure of electrical power units was increased from an average of 54,000 miles to 112,000. Accessory apparatus is repaired at work-benches assigned to each respective class of units.

Procedure for Engine Repairs

Engines are sent to the shop only when complete rebuilding is necessary. This is based on 90,000 miles of operation, except for accidents. All minor repairs are made at the operating garages.

A continuous record of each engine is kept which is similar to that of power generators and motors. Upon receipt of a powerplant in the engine department, it is completely taken apart and the parts cleaned, after

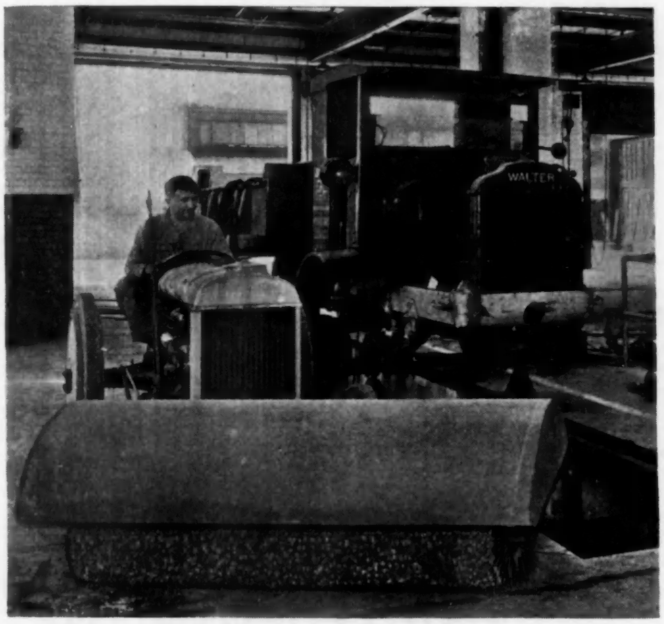


FIG. 11—THIS POWER BROOM SERVES TWO PURPOSES

Cleaning the Shop Floor Is the Function Ordinarily Associated with This Piece of Equipment, but When Necessary It Serves as a Tractor To Move Chassis along the Production Line

which they are inspected and the necessary replacement parts procured for reassembly. Crankshafts are examined and checked. All bearing-surface diameters are checked with a micrometer gage. Regrinding is done in the machine-shop, if necessary. Standard undersizes of 0.01, 0.02 and 0.03 in. have been established. Fig. 3 shows the engine-testing equipment. Connecting-rods are selectively assembled with regard to balance and weight. Cylinder sleeves and pistons are checked by micrometer gages and assembled according to standard clearances and tolerances. Carbureters and other necessary parts are sent to their respective work-benches to be reconditioned. Constructive changes are made in the engines to bring them uptodate, and complete tests which assure standard performance and reliability are made before they are released for operation. The result is a remanufactured engine that has more power and more miles of life than when it was originally put in operation.

Other departments, such as rear-axle, front-axle, brake-relining, radiator-repair, upholstery, sash and battery, take care of their respective units. The machine-shop, wood-working, blacksmith and sheet-metal departments act as contributing shops for the other detail departments and main-line assemblies.

Main Assembly Line

The main lines have the appearance of production assembly-lines, except that they include dismantling and stripping. Fig. 4 shows the progressive general-overhaul lines. The motorcoaches are sent to the shop for general overhaul after 90,000 miles of service. They are washed with water and steam and the major units then removed. Body panels are stripped, sash removed, flooring repaired and all other necessary replacement and constructive changes effected.

As the vehicle proceeds along the line, the major units are reinstalled. Inspection is carried out by the line foremen as the work progresses. The reassembled motorcoach is delivered to the paint shop, which is in a separate building. After the painting is completed the vehicle is returned to the final-inspection end of the production lines, where the brakes are adjusted and tested on a brake-testing machine before the motorcoach leaves the shop. Each vehicle is road-tested and then delivered to the garage to which it is assigned.

Adequate Tools and Shop Equipment Pay

Probably the most remunerative means of applying production standards to maintenance is by the use of adequate tools and shop equipment. Training labor to use tools and equipment for the production of maintenance as well as for the manufacture of apparatus is much easier, more productive and more economical than to obtain the results by their application of ingenuity and mechanical skill. The psychological effect of rapid production and ease in obtaining it is stimulating to the entire organization. The value of machine-tools and equipment cannot be correctly calculated from their direct production of saving in labor, although these factors alone are frequently considered.

Of course the purchase of tools and equipment and their liquidation has an economic limit. In the retail-maintenance business they may be paid for by direct charge for their production. In an operating maintenance-shop tool investments are carried as equipment capital and the earnings dissolved in maintenance cost. The proper coordination of tool equipment and operating equipment is largely a matter of experience, foresight and judgment, supplemented by an investigation and analysis of the value of each device.

Very many hand-tools and large wrenches are required in the garages and shop, and many of these are designed expressly for the purpose for which they are to be used. They can be made in the shop or by tool manufacturers to special drawings for specifications. All hand-tools are given out on a paper check that is signed by the workman and represents a receipt from him for the tool. The check is returned to the man upon return of the tool.

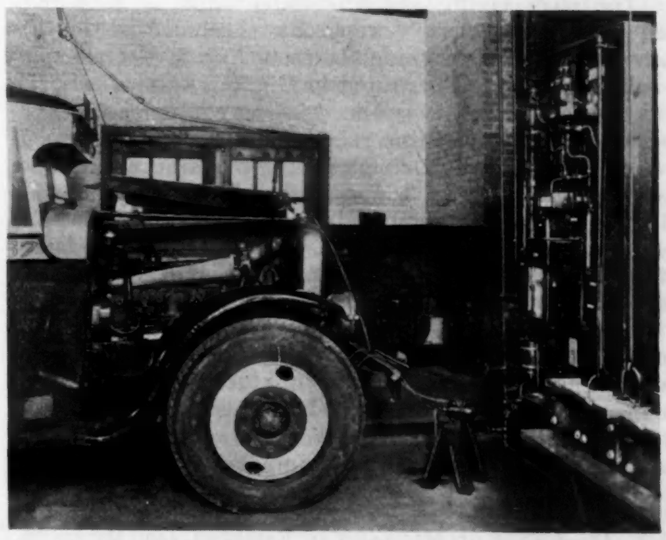


FIG. 12—EXHAUST-GAS-ANALYSIS EQUIPMENT

This Has Saved Time in Effecting Economies in Fuel and Lubricant Costs and in Increasing Engine Power To Meet the Demands of Heavier Loads and Faster Schedules, by Establishing Definite Standards for Carbureter Settings, Exhaust Back-Pressure and Carbon-Monoxide Content

An electrically heated soldering pot, shown in Fig. 5, was designed by our own organization, using standard immersion-heaters and control. This device saves 1½ to 2½ hr. per commutator in armature repairs. The operation is similar to that employed by large manufacturers of electric motors. The design embodies their principle, with some unique improvements in construction. The container is made of arc-welded fabricated steel and is insulated on all sides and at the bottom with 4 in. of insulating powder. Heating-units having a total capacity of 10 kw. are installed. This is sufficient to raise the tin from room temperature to the soldering temperature in approximately 2½ hr. The average power demand is very low, owing to good heat-insulation.

Pure tin is used in soldering the commutators. Oxidation and the formation of dross are prevented by a thin layer of insulating powder over the molten metal, a small ladle being used to scrape the powder aside and prevent it from coming into contact with the commutator during the soldering operation. Rubberized adhesive tape is wrapped around the commutator near the risers to form a seal between the adapter plate and the commutator. The molten tin is caused to flow into the soldering chamber by immersion of the displacement ram. This ram is over-counterweighted to prevent its accidental immersion, which would cause loss of tin. The temperature of the tin is automatically maintained by thermostatic control.

The advantages of this method are thorough soldering of all leads, saving of tin and increased rate of production. The actual soldering time, that is, the length of time during which the tin is in contact with the commutator, varies from 3 to 5 min., depending upon the size of the commutator.

The function of the dynamic-balancing machine illustrated in Fig. 6 is to secure smoother operation and longer life of the equipment. It is used to balance generator and motor armatures and is adaptable to the balancing of crankshafts.

Special Labor-Saving Equipment

The labor-saving and productive value of shop tool-equipment is generally apparent. Included in this list are the washing machine shown in Fig. 7, electric spot-welding machine illustrated in Fig. 8, electric-arc welding-machine, oxy-acetylene welding-equipment, crankshaft-grinding machine, sheet-metal machines, woodworking machines, Brinell testing-machine and scleroscope shown in Fig. 9, mechanical sledge-hammer used in the blacksmith shop and many others. A specially designed universal hoist, illustrated in Fig. 10, facilitates the handling of large units in the garages and shop. The platforms can also be moved by a lift-truck. The power broom, Fig. 11, serves two purposes. In addition to cleaning the shop, it is used as a tractor to move the chassis along the production lines. Many hand-tools, such as compressed-air chisels and wrenches, electric drills and screw-drivers and numerous others, are used. The removal of molding and panels by cut-

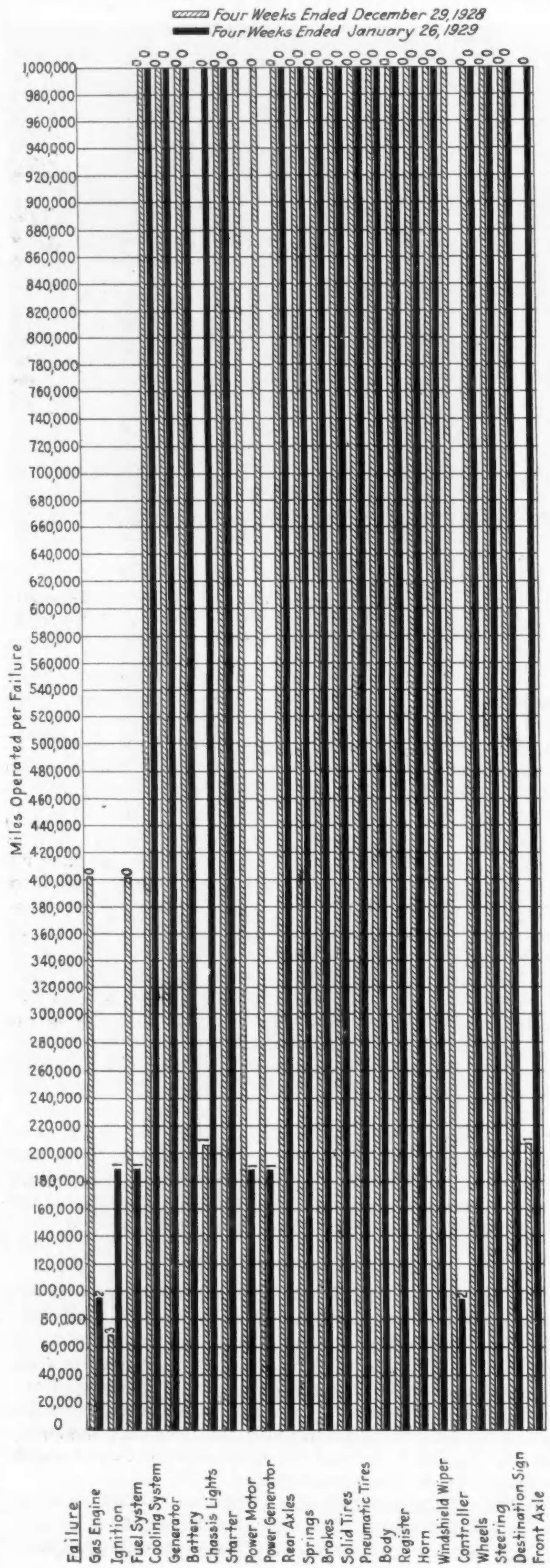


FIG. 13—CHART OF MECHANICAL FAILURES AND MILES OPERATED PER FAILURE

This Chart Covers Not Only Delays in Schedules but Also All Work Done on the Equipment between the Scheduled-Repairs Periods. Two Four-Week Periods Are Covered by the Chart, and the Figures at the Ends of the Blocks Indicate the Number of Failures of Each Type That Occurred

ting off the screws, instead of removing them by hand or power screw-driver, saves 32 hr. per vehicle in this particular operation. The hand method took 64 man-hours; the air method, 32 man-hours.

In the automotive testing laboratory the equipment is more complete, so that analytical and development tests can be conducted. Included in this equipment is a floor dynamometer, similar to those used by the larger manufacturing plants, which is used for determining the over-all output measured in torque delivered by the rear wheels. This is adaptable to all types of vehicle.

An exhaust-gas analyzing equipment, Fig. 12, is used to establish definite standards for carbureter settings, exhaust back-pressure and carbon-monoxide content of the exhaust. This device has been found to be a great time-saver in accomplishing economies in fuel and lubricant cost and in increasing the engine power to meet the relentless demand of heavier loads and faster transportation.

In the paint shop, appreciable savings have been effected by the introduction of spraying. Two and one-quarter hours was required to apply two coats of paint

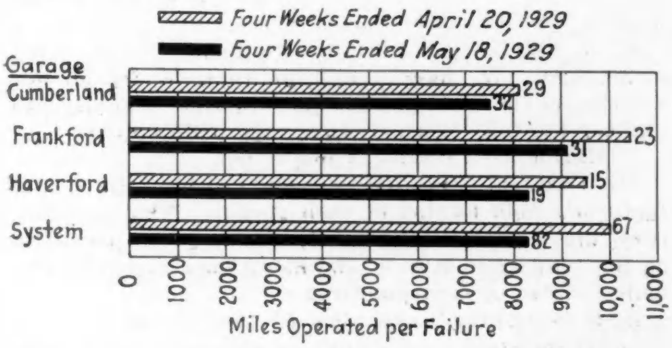


FIG. 14—SIMILAR CHART FOR THE PHILADELPHIA MOTOR-COACH SYSTEM

This Chart Gives a Comparison of the Mechanical Failures Given Attention in Each of the Three Garages and for the Entire System, as Well as the Mileage Operated per Failure. These Charts Are Posted on the Bulletin Boards of the Garages and Create a Spirit of Competition

to the roof of a double-deck motorcoach. This is now done by spraying in $\frac{3}{4}$ hr. Chassis formerly required 2 hr. of hand-painting. This is done better by spraying, and only half the time is required.

Repair Methods Standardized

Standardization of repair methods is in accord with standardization of equipment. It amounts to training the personnel to maintain one type of equipment in a single manner. This calls for centralization of instruction. To bring about this condition, a manual known as Standard Practice is used. It is compiled by the engineering personnel and distributed to all garage and shop foremen. The purpose is to accumulate and disseminate all data in one centralized form. All subjects pertaining to maintenance and garage and shop procedure are included. The standard clearances and tolerances are specified. The contents are bound in loose-leaf form to facilitate additions and revisions. All copies are called in for examination at regular intervals.

The value of standard practice is advantageous in maintaining standardization of constructive maintenance, particularly where design changes are to be effected when repairs are necessary. In constructive and progressive maintenance the standard-practice manual serves as a record of changes that have been effected in the past.

Brevity is essential in the preparation of standard-practice data. This is attained in many cases by the use of drawings that are inserted in the form of photostats on a standard-size sheet.

This manual serves as a record to which all foremen can be held responsible for the proper execution of repairs. It adds flexibility to the organization in transferring and promoting men. It instills confidence in their ability. It is also a great time-saver for the executives and members of the engineering department, as it eliminates hours of individual instruction and many group meetings.

Material Inspection and Salvage

Materials coming into the receiving department are inspected for defects. This inspection may include a Brinell test on such items as axle shafts or other steel parts on which rigid specifications must be maintained. Micrometers and gages are used to check the dimensions of parts. Defective parts are promptly reported to the vendor and replacement obtained. Attention to these details results in savings by averting trouble in assembly and in service. The principal purpose of checking incoming material is to avoid defective parts or parts that are not suitable for the service for which they are intended. A noteworthy example was a shipment of cylinder-head gaskets costing 11 cents each, which, for some reason, were not inspected and were distributed to the garages for use in motorcoach engines. Nothing happened until more than 100 engines were equipped with these gaskets, when trouble began to develop very fast through failure of the equipment. The gaskets were not made of the right material and permitted water to pass from the water-jackets into the cylinders, in a few cases wrecking the engines and in other cases causing serious delay in schedules.

The salvage department receives all defective or damaged units and parts that are sent from the garages to be repaired or scrapped. The units to be repaired are sent to their respective departments, accompanied by a shop order. Scrap material is sorted and sold.

From time to time changes in shop arrangement, production routines, maintenance operations and personnel are necessary to meet changing conditions and introduce worthy suggested improvements. A progressive reaction should be taken toward these circumstances.

Securing More Equal Service from Parts

One of the most difficult problems of maintenance engineers is one to which we feel that manufacturers do not attach sufficient importance; that is, the matter of a well-balanced life of the component parts of a vehicle. Many of the vehicles in service today have a high percentage of their component units that can be serviced in such a way that the vehicle will remain in continuous operation for 10,000 miles, but other units in the same vehicle require service after 3000 to 5000 miles. Constructive maintenance involving change of design is necessary on the part of the operators to increase the life of the low-mileage units to secure a properly balanced vehicle in which the average mileage between scheduled repairs will permit the operation of vehicles in long-distance service.

We find that comparative charts issued to our or-

ganization at four-week periods bring out the weaknesses in maintenance and equipment, so that effort can be concentrated on the units or parts of the vehicle that require frequent attention. Fig. 13 shows the mechanical failures in miles operated for one Mitten Management company. These failures represent not only delays in schedules but also every mechanical failure requiring attention, such as changing a spark-plug, tightening a fan belt or work of any nature done on the equipment between scheduled-repairs periods. This record is based upon the theory that the scheduled repairs should be made in such a way that the motorcoach can be operated by the transportation department continuously without any attention from the mechanical department until the next scheduled-repairs period.

Fig. 14 shows another motorcoach operation under Mitten Management, having three garages. This chart is prepared to give a comparison of the mechanical failures in each garage, the chart being posted on the bulletin boards, thereby creating a spirit of competition among the men in the mechanical force at the various locations.

THE DISCUSSION

T. L. PREBLE[2]:—This paper is one that will serve as a further illustration of the increasing tendency toward a scientific approach to maintenance problems, particularly in the larger repair-shops of manufacturers and owners. The old catch-as-catch-can methods of maintenance are being replaced by others drawn in a large measure from production. The lessons that can be learned from production are many and valuable, although in all fairness I must add that the motor-vehicle production department can itself learn much from the maintenance man.

The chief objective of mechanical repair work is jobs done quickly and well and at as low a cost as adherence to quality workmanship will permit. Only through the attainment of such an objective can we have assurance of the minimum of maintenance expense and of idle-vehicle time. In attaining this goal the industry is faced, for example, with the highly involved problem of repair-operation standardization. The aims of the intelligent maintenance man and of the production man are similar. The following quotations[3] from statements made by production men are surely applicable to the problems of the maintenance executive.

> No record can, as a rule, be kept of men doing miscellaneous work unless the work is properly planned ahead of time with that object in view. If it is intelligently planned, an improvement will result which will far more than pay for the expense of planning and record-keeping.—H. L. Gantt.

> The main trouble with the majority of departments operated chiefly by manual labor is the lack of correctly determined standards of every move.—Frederic A. Parkhurst.

> Two fundamental principles of cheap production lie hidden away among inefficient shop processes, bewildering disorder of shop conditions and lax, inaccurate and utterly misleading shop methods: (*a*) the determination of a standard time for each job and its tabulation, introduction and enforcement and (*b*) the absolute elimination from the workman's routine of every duty but that of running his machine continuously and efficiently.—Charles U. Carpenter.

On this interesting and important development we have been favored by a paper from a man who knows the subject thoroughly and whose presentation of it, I am sure, gives us some highly interesting and equally practical and usable ideas. Little has been said in the past on this subject, but I believe much will be said in the future.

A MEMBER:—Everything but the tires seems to have been covered. I should like to know how Mr. Hewitt handles the tire end of the service.

H. B. HEWITT:—We let the tire manufacturer worry about that. We have a mileage contract for all our vehicles on the system, with the exception of snowplows and service trucks, which have very little mileage.

A MEMBER:—I mean the inspection.

MR. HEWITT:—Our tires are checked by a tire manufacturer's man located at each garage. The manufacturer also has a man constantly checking tire pressures on the vehicles in service, and he makes a report of any underinflated or damaged tires.

R. E. PLIMPTON[4]:—In view of the specialization in your organization, particularly in connection with overhaul or heavy repair-work, do you pay the mechanics on some piecework basis?

MR. HEWITT:—We did have some piecework prices in our cab garages. We had the scheduled repairs and also some of the unit repairs on the piecework price, but found that very close supervision was necessary, and we had more road failures, so we have entirely discontinued any piecework in favor of the group plan.

B. H. EATON[5]:—Do you use reclaimed oil?

MR. HEWITT:—Yes, we have a central reclaiming-plant that takes care of everything for the system. That includes wool waste from the journal boxes on surface and subway cars and wiping rags from all the shops. The waste and wiping rags have the oil and grease extracted by centrifuge machines and are washed in standard washing-machines similar to those used for mechanics' overalls. The cost of reclaiming the cylinder oil from our engines is 11 cents per gal., which includes transportation between the garages and the reclamation plant.

MR. EATON:—Do you mix that oil with new oil?

MR. HEWITT:—No, it comes through sufficiently close to the original specification that we do not need to worry about that at all. However, we do check every batch before it is released. Once in a while something slips and the batch is either run through again or thrown out.

Extent of Applicability of Method

MR. PLIMPTON:—The practices and principles that Mr. Hewitt describes relate mostly to an operation distinctive in size, concentration of routes covered and

[[2] Mr. Preble, who is assistant general manager of the Brockway Motor Truck Corp., of New York City, was scheduled to preside over the session at which this paper was presented, and the accompanying remarks are substantially what he planned to say in introducing the author. He was unable to be present at the meeting, and his remarks are, therefore, printed as part of the discussion.]

[3] See Estimating the Cost of Work, by William B. Ferguson, pp. 159, 160 and 162; published by Engineering Magazine Co., New York City, 1919.

[4] M.S.A.E.—Associate editor, *Bus Transportation*, Chicago.

[5] M.S.A.E.—Motor-vehicle supervisor, Bell Telephone Co. of Pennsylvania, Pittsburgh.

diversity of equipment. Many companies maintain motor-trucks and motorcoaches. A fair number do this in limited metropolitan areas but few have the combination presented in Philadelphia, where a total of 2100 motor-vehicles are operated in a single city. Some of the motorcoaches may be of the intercity variety but they work on routes that are short enough so they can be brought into the Philadelphia shop and garages at short and regular intervals. In view of these unusual features, Mr. Hewitt's opinion as to how far the practices of his company can be applied by smaller local operators of motor-vehicles or to what extent they could be used by larger companies which, because of their decentralized field of operation, take on to a large extent the maintenance characteristics of the smaller companies would be interesting.

This subject should be of vital interest not only to motorcoach operators but also the many firms operating motor-trucks in sizable installations. It has a bearing also on the small fleet, since that may need the application of production standards, as Mr. Hewitt expressed it, even more than the larger operation. The latter presumably has the personnel and equipment to do a much better job. Since maintenance policy must be determined primarily by the number of units handled from a given shop or base, considering the following three groups may be helpful in this discussion:

(1) Large companies, say with 100 motorcoaches or 500 motor-trucks, that might use, in part at least, the production standards advocated by Mr. Hewitt

(2) Those of medium size, with perhaps 20 motorcoaches or 100 motor-trucks, that might be interested to a limited extent in production methods

(3) Small operators, with as few as 5 motorcoaches or 25 motor-trucks, who would probably apply production standards, if at all, only by proxy; that is, by farming their work out to factory or specialized service-stations

Of course these divisions are arbitrary, and factors such as location, initiative of personnel, capital available for investment in buildings or shop equipment or lack of such capital and initiative, might place any one of the groups above or below the average situation just outlined. To get closer to what is a very complicated subject, we can consider separately the following elements:

(1) Equipment to be maintained
(2) Physical facilities such as shops or garages
(3) Tools or shop equipment
(4) Maintenance personnel
(5) Standards or methods
(6) Unit parts versus reserve vehicles

How far, then, can these three groups of companies or operators be expected to apply production methods or standards, either in keeping equipment up to par or in actually improving its performance and in setting back the obsolescence clock? All these purposes are convincingly outlined by Mr. Hewitt in his paper. The author properly calls attention to the economy when operating equipment is standardized. He is fortunate in his particular installation. Very few motor-vehicle operations have the same degree of standardization, and even Mr. Hewitt must depart from it, since the three types of vehicle—motorcoaches, taxicabs and motor-trucks—immediately set up an off-standard condition. In most operations, even though specializing on one form instead of the three handled at Philadelphia, the conditions must be even worse. Different makes, sizes or capacity and models all lead to complexity in methods, training of personnel and physical facilities that cannot, and probably never will, be avoided.

Physical facilities, the second element listed above, are of the most production importance to the larger companies. The ones that can lay out separate shops and garages are very few. However, much progress is being made in laying out buildings so that overhaul and current repair work can be separated and the vehicles can flow through the building in the most direct line and most conveniently for the work that has to be done. The only way the smaller operator can take advantage of this as a rule is by completely transferring the maintenance work to others. By doing this work for a dozen small operators say, the factory service-station can, of course, apply production methods. Its building facilities can be designed for expeditious handling, whereas the smaller operators would be fortunate if they had one space for all the different kinds of maintenance activity.

Until recently some difficulty has been experienced in getting tools or shop equipment designed for heavy-duty service, such as would be required in motorcoach or motor-truck garages. This is now being overcome and a wide variety is available for the larger operators. The third group undoubtedly would be interested only in the smaller and simpler forms of tools. The larger companies and, in a few special cases, those of medium size, will take the initiative and design and build special tools that they may find are desirable, thus leading the way for the commercial development of such devices.

T. L. Preble

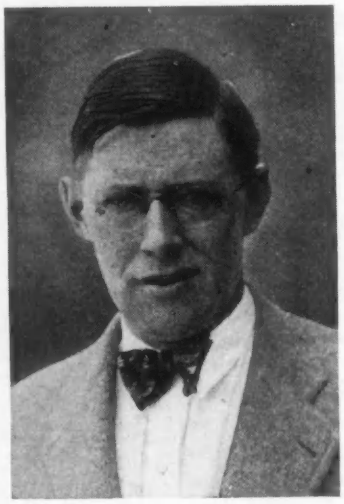
Maintenance Personnel Problem

Lack of training and of incentive are probably the most important reasons why maintenance personnel does not keep pace with similar workers in the factory. A few companies have formed classes to educate their mechanics or have endeavored to hire those having some vocational-school background. The main difficulty here is probably due to the lack of training of foremen, particularly in the business aspects of maintenance. They may know the equipment very well, but are not likely to be so familiar with cost-keeping, handling of men or planning of work, which cannot be passed on to specialized departments as is often the case in a factory organization. The lack of incentive applies particularly to the mechanics and other men on the firing line. This has been supplied by a flat-rate system in many service-stations but so far little encouragement or financial reward for good work apparently is offered mechanics in the shops or garages of the companies operating motor-vehicles.

In view of the lack of standardization of equipment and of the jobs that must be handled by the average men, standardizing methods even in the larger installations of motor-vehicles will be difficult. A more hopeful possibility is offered in the standardization of dimensions. A few of the larger operators have adopted the standard S.A.E. oversizes for pistons and piston-rings and have gone farther in specifying tolerances for other wearing parts. The operators who have not the volume of work or the experience necessary to determine what is good practice in wear can well take advantage of the study made by the manufacturers. One company, at least, in the heavy-duty field is studying this subject thoroughly to be able to tell its customers just when wearing parts have reached the end of their useful life.

Application of Unit Repairs

The idea of unit repairs is generally accepted in theory by operators, at least by the larger ones, but it is often difficult to carry it out in practice. Motorcoach companies must always keep a number of extra vehicles over and above those required for probably three-fourths of the working time. Here again difficulties are caused by lack of standardization of equipment and the expense that would be necessary in stocking extra engines and other unit parts. The general tendency, therefore, is to keep the investment in unit parts down to the minimum, to depend upon the ability to make repairs during the off-peak period and then use reserve vehicles and hope that the others will be back in service in time to help take the peak load. The manufacturers of heavy motor-vehicles have helped in solving this problem, either by putting out units and other parts on consignment, so that the operators do not have to pay for them until used, or by carrying reserve units at their service stations to be available at once for replacement purposes.



R. E. PLIMPTON

The availability of unit parts is coming to mean that even heavy repairs can be made with the minimum out-of-service time by having one important part changed at a time as performance of the vehicle may indicate, rather than following the method current five or six years ago when the rebuilding of every unit of the complete vehicle at intervals determined by time or miles covered was thought necessary. In contrast with this, when no attempt is made to carry spares of important units, the complete vehicle is likely to be out of service for a long time when major repairs are necessary. Unit repairs make possible the planning of maintenance work, assigning regular duties to the maintenance personnel, adopting standard tolerances and using uptodate and efficient tools and shop equipment. Thus the unit-repair system controls virtually all the important elements of maintenance.

If production standards are to be adopted, as so convincingly advocated by Mr. Hewitt, much more consideration must certainly be given to unit repairs. When this knotty problem has been solved, the most economical investment in unit parts for a given operation determined and these parts are kept in stock all the time, the operator may attempt to carry out the kind of constructive maintenance advocated in the paper. In general, however, most operators have not the experience or the testing equipment needed to secure good results in rebuilding equipment. Instead of improving it or overcoming a difficulty, their efforts may lead only to more trouble. Better results will be gained if they pool their experience with the engineering department of the manufacturers to improve construction.

Planning and Instruction Need Improving

MR. HEWITT:—The comments by Mr. Preble are of unusual value, since he has been in very close contact with both manufacturing and maintenance in the field. He has pointed out one of the spots where probably the greatest improvement can be made. That is planning by executives and detailed and thorough instructions to foremen and workmen. We have done some work along these lines in that we are preparing specifications for jobs by vocations and by classes in each vocation. These specifications indicate what a man should know to qualify for each job and what personal tools he would be required to have to enable him to do the work properly. This is a very large undertaking and undoubtedly will take considerable time for completion.

Mr. Plimpton's separation of groups of motorcoaches and trucks into various fleet-sizes brings up a question that is being given considerable thought by various management organizations. One company that has been operated for several years by Mitten Management had a mixed fleet of 11 gasoline-electric motorcoaches of 2 different models and 14 mechanically driven vehicles, 12 of one manufacturer of 2 different models and 1 each of 2 other manufacturers. The work done in this group was planned on a definite-schedule repair-program, replacements of worn parts being made by new parts. The remanufacturing or reconditioning of parts, which was considered economical, was done by a local machine-shop. Body work or accident repair-work was practically all done in the garage by competent woodworkers, with the exception of motorcoaches that were very badly damaged by accident, and this was let out on contract to local body men. Experience indicated that the economical procedure was to standardize on gasoline-electric motorcoaches, and therefore all of the mechanically driven vehicles have been replaced.

Mr. Plimpton has brought out some very important points in maintenance that were not included in the original paper and I suggest that some of his points might be considered for future papers. They are:

(1) Interchange of engineers between manufacturers and operators
(2) Methods of increasing the load factor on commercial vehicles. I suggest that this be divided into two sections, one for passenger-carrying vehicles and the other for vehicles carrying merchandise
(3) Practical methods of instructing maintenance foremen and mechanics
(4) Standardized classification of maintenance men.

Maintenance and Inspection Methods

By J. G. MOXEY[1] TRANSPORTATION MEETING PAPER

THE NECESSITY for paying close attention to the details of maintenance and inspection methods is emphasized by the author, who defines preventive maintenance by repeating the adage, "A stitch in time saves nine." After outlining why the detailed coverage of a fleet is essential and stating the methods by which this can be accomplished, he presents an outline of the field-inspection organization developed by his company and explains some of the inspection practices it uses.

Cooperation between the workers and the management is furthered by district meetings of the inspectors which are held at stated intervals and whereby the various problems the employes have in their respective territories are settled without delay by representatives from the home office. Overhaul schedules are discussed, and it is stated that such a schedule is allowed to go into effect only if each vehicle indicated has performed a sufficient amount of work since its last overhaul, based on the gallon-mile effort as compared with the general average for that type of truck.

The unit-replacement plan is practised by the author's company, and this is described. As regards retirement, only three reasons for it exist, in the author's opinion; namely, obsolescence, in cases in which the vehicle is so old that parts cannot be obtained for it from the manufacturers; inability of the machine to perform the work assigned it; and the high cost of that particular type of vehicle as supplied to a specific operating problem.

Another subject discussed is the operator's responsibility to salesmen. In conclusion, the necessity for preventive maintenance is reiterated.

In the discussion, statements are made that maintenance technique needs further development, that there are definite and plentiful indications of the engineering approach to maintenance problems, and that this trend toward an increasing dignity and a more completely recognized importance of automotive maintenance will prove to be of inestimable value to the industry.

Engineering and service relationships and numerous problems and methods of service departments are discussed. Among these are the importance of maintaining stocks of repair parts where they are readily available to fleet owners, suitable forms on which the operator can record essential information for the ordering of parts, and questions of obsolescence, the raising of money with which to purchase new equipment, and whether the factory branches should make deliveries of parts to fleet operators.

WHEN ONE considers that 45 per cent of the gross income of a corporation such as I represent is spent in some form of transportation, such as pipe lines, steamships, railroads and motor-trucks, and, further, that one-third of the total marketing expense alone is spent for motor transport, the necessity for paying close attention to the details of maintenance and inspection methods is at once apparent.

Our company operates the main portion of its fleet of motor equipment in the State of Pennsylvania and it alone constitutes the most concentrated fleet of its size in the United States. It has 1000 or more vehicles in that territory and operates them from tank-wagon districts having an average working radius of about 20 miles and an average mileage per machine of only 25 to 30 miles per day. This furnishes an indication that many of the transport problems as commonly understood utterly fail in their application to such a fleet.

One of the basic thoughts back of any successful inspection and maintenance method is that of saving the money before it is spent, and I shall analyze that method; first, by repeating the adage that "A stitch in time saves nine," as a definition of preventive maintenance.

Detailed Coverage of a Fleet Is Essential

Systematic, periodic and thorough coverage of a fleet in all details constitutes the secret of the proper functioning of a maintenance program. As an instance of being systematic, we have a motor-truck-inspection report on which are listed 69 questions relating to the physical and mechanical condition of a vehicle, and it is the duty of the district inspector to indicate on this report either "yes" or "no" or some qualifying notation such as "fair," "good," and the like, after every question. The questions are printed so that a "yes" answer is not necessarily a positive answer to a question. The questions are framed so as to avoid the pitfalls that so many inspectors fall into, such as "yessing" the boss's style all the way down the line. The report blank was devised purposely to break up such practice; a check mark on it means nothing.

An inspector is required to visit a machine and report upon it, make his notations, sign the report, have it signed by the driver in charge of the vehicle, retain a copy for himself, and send a copy each to the district office and the central-control office as a notification from all and to all the parties concerned that certain conditions exist on that vehicle which need attention.

Within four weeks the inspector is required to fill out a correction report, which is really a follow-up of a defective condition, with notation of the correction applied and the date it was made. The inspector fills in the number of the condition, and not the details. For example, question No. 5 reads: "Is fan belt in good condition?" If the answer reported is "no," a new fan-belt is ordered and, when installed, a notation on the bottom of the correction report gives the date and reads: "No. 5, new fan-belt installed." This report must again be followed in approximately six weeks by another initial-inspection report so that full coverage

[1] Supervisor of motor transportation, Atlantic Refining Co., Philadelphia.

of each machine will be made at least five times a year. Having 300 to 350 tank-delivery centers within the territory makes it impossible to bring all these machines to a few central points and, for this reason, the inspector visits the machine.

Our follow-up method consists of noting in black ink on a list of machines, by location and number, the date of filling out the initial report and, showing in red, the correction-report date, with a red circle around the initial-report date for which the correction report was issued. This then shows the vehicle to be in good condition for further operation. The office-control record reaches the office of the supervisor each month, and he can scrutinize it carefully and pass upon whether the work of the inspectors is producing good results, then to take such action as will remedy defective conditions.

Field-Organization Inspection

Regarding the field-inspection organization, the main marketing-divisions may not be large enough to keep an inspector busy, but an effort is made to lay out inspectors' divisions so that each man will have a reasonable amount of work, based not only on the number of vehicles but upon the mileage the inspector must cover in systematically going over his territory. The field inspector functions as a unit of the field marketing-district and looks to the home control-office only for the systematizing and standardizing of his work in the field, which constitutes an important point.

The inspector cooperates with the driver in properly maintaining his vehicle, and the driver is expected to operate his vehicle for the safe delivery of his product to the trade. The inspector forwards to the field office a list of the parts needed to maintain the vehicle, as indicated in the initial-inspection report, and the parts are ordered by that office for forwarding by the stock depot of that section. In extreme emergencies, however, the parts are ordered by the inspector direct from the stock depot; also in emergencies and when the inspector is not available, the driver may order parts, forwarding his order through the field office of his district, thus combining the responsibility of the field office with that of the home office in maintaining and operating the vehicle, which eliminates any "passing of the buck."

In maintaining his vehicle the driver keeps the crankcase and radiator filled to their normal levels and does other routine work; but, to tie that man definitely to some kind of control, he is required to make out a driver's truck-report monthly, stating thereon that he has definitely performed all the work specified upon it, as well as reporting any defective conditions. The driver signs this report, sends it to his district manager for signature and he in turn signs it and sends it to the home office. A similar control of this record is kept in the central control-office, as in the case of the inspector's report and follow-up.

District meetings of the inspectors in our various marketing divisions are held at which a definite prearranged program is followed and definite settlement is made of the questions raised after these have been discussed thoroughly. Thus the various problems which these men have in the territory are settled without delay by representatives from the home office.

Cooperation Between Workers and Management

We instruct the inspectors to do any given job in some certain way which follows the generally accepted practice as regards standardization of maintenance methods. Further, we have a motor-truck committee that meets each month and includes representatives of the stock, shop, and vehicles. The records of the decisions made are released by the secretary of that committee to the field in general and become in a certain sense the company's encyclopedia of maintenance. This committee in no way functions with regard to operation.

J. G. MOXEY

Shops located at approximately the center of machine distribution carry the parts, and service repairs are made from these shops. A main marketing-district is divided into three or four individual shop-districts, each of which is a self-supporting unit run by local personnel. On service repairs, the inspectors and drivers work in cooperation with one another, and our drivers are their own maintenance men to a very marked degree.

Among the instructions to the drivers are that they shall not touch the underside of the engine, the inside of the transmission except the cover-plate and shifting-fork assembly, the inside of the differential and the inside of the magneto, except the breaker box. A driver is permitted to work on these parts only after direct instruction to do so by the inspector in charge. The inspector is, of course, continually being guided by his personal knowledge of the driver as to his capability of handling work of this kind. As an example, suppose a bearing burns out. The inspector may be 75 miles from the driver when the latter telephones. The inspector may know that the driver is not capable of installing a new bearing and therefore will instruct him to drop the crankcase and get everything ready for work, meanwhile trying to find out which bearing is in trouble; but the driver is also told not to do any other work until the inspector reaches the scene and installs a new bearing.

Practice Regarding Overhaul Schedules

An overhaul schedule is determined from reports by the inspector who circulates in the territory, and is backed by the chief inspector and compiled by the staff for submission to the control office. This schedule is allowed to go into effect only if each vehicle indicated has performed a sufficient amount of work since its last overhaul, based on the gallon-mile effort as compared with the general average for that type of truck.

Statements of our overhauling schedules are not sent to the marketing division because, when such information is available and it is known that a certain vehicle

is due for overhaul at a given time, the driver may slight his work and thus neglect adequate maintenance.

Control on the economic maintenance of the vehicle is secured when the staff of the central control-office goes over the record of each individual vehicle every six months and determines whether the operating expense or repair costs are within the allowable limits for that period for that particular type of unit. If the repair costs are excessive, the maintenance division is notified immediately and investigation in the field follows, so that the excessive cost is stopped at once. Quarterly surveys of this sort, formerly made, were found to be unnecessary because the different vehicles do not, as a rule, get into bad condition in such a comparatively short period.

Unit-Replacement Plan Practised

We find that, under general conditions, the unit-replacement plan is best for complete maintenance. With trucks assigned to definite classes of work in which each machine must be kept active to the maximum extent, any repairs, aside from washing, oiling, greasing and general tightening of the parts, which are done by the driver, must be sandwiched in; therefore a small amount of leeway in the scheduled allotment of work to be done is allowed for unexpected repairs.

The shops are operated at no profit to ourselves. In a recent debate with some manufacturers on the subject of service-station-depot maintenance as compared with that of the owner-operator, we lost the verdict; but, afterward, a district service-manager of a certain truck-manufacturing company told me that one-fifth of his company's total income was represented by the returns from its maintenance and service depots.

The perpetual-inventory method is used for stock records, which are kept at the central-control office. When a part goes into the field for use, a record is immediately sent to the home office so that the stock supply can be controlled by setting definite maximum and minimum allowances for that particular part. These allowances are reviewed periodically by the maintenance committee so that plans can be made for requirements for seasonal peak-loads. As to "pirate" parts, we do not use them.

As an example of the benefit arising from a study of maximum and minimum amounts of stock needed, about seven years ago a particular depot had a stock inventory of \$513,000 which represented an investment per vehicle of \$1,400. After inquiry among several representative manufacturers of trucks, I told our controller that the logical amount of stock for that depot was \$75,000 to \$80,000. Today that depot has a stock on hand of approximately \$66,000, or an average of \$125 per vehicle; and we have not yet reached the low point.

Painting Materials and Methods

Materials that can be used under varying conditions and which are very valuable to operators have been put on the market by the paint manufacturers in recent years. Our company was one of the first to use lacquers on commercial vehicles, and we have kept in touch with the manufacturers and are today using lacquer to good advantage. The painters, who start out in the spring, go to the various trucks in the field and can completely finish about three or four trucks per week per man.

Success can follow only close coordination of operation and maintenance. When something mechanical goes wrong in the field, we turn to the operating division and ask whether that district can lay up a vehicle for the time needed to replace an engine or other part, or whether a relief vehicle must be put into service.

Only Three Reasons for Retirement

Based on careful studies, I believe that the economic life of a motor-vehicle is indefinite if it is properly maintained. The retirement of a motor-vehicle can be justified, in my opinion, by only three reasons: (*a*) obsolescence, in cases in which the vehicle is so old that parts cannot be obtained for it from the manufacturers, (*b*) inability of the machine to perform the work assigned it, and (*c*) high cost of a particular type of vehicle as applied to a specific operating problem.

A few of the truck manufacturers do not permit obsolescence to creep in, parts of new design being made interchangeable with old parts. Inability to perform the work is prevented by not allowing a vehicle to remain in a class of work for which it is not suited; it is transferred to the kind of work for which it is best adapted.

Regarding factor (*c*), if the right type of machine for the particular operating problem has been selected, the operating expense of two vehicles built by two different manufacturers and operated side by side or even in different comparable districts will not differ by very much; it is virtually impossible to retire either machine on this basis under these service conditions.

Items of General Practice Mentioned

Special studies of parts and materials that enter into the maintenance of the vehicles of a fleet are vital. We found, for example, that certain specific characteristics must be included in brake-lining that will assure safe and economic operation of our vehicles and that this information was best obtained from the honest-to-goodness service-engineers at the factory. We have made tire studies for years and have valuable data as a result. Our most important finding, which was transmitted to the purchasing department and supplied the basis for a code of purchase of tires, was that the maximum tire mileage is assured by suiting the type of tire to the needs of the vehicle. Tire manufacturers seem at last to realize that their success lies not wholly in the quality of their product but also in the correct application of the product to the work to be done.

Operator's Responsibility to Salesmen

Reciprocity fleets should be avoided. By this I mean that simply because a certain good customer for the commodity your company has for sale happens to market an X. Y. Z. truck is not a reason for putting that truck into your fleet.

The difficulty that the salesmen have in understanding engineering language should be overcome. It swamps them. Our duty as transportation men is to make the salesmen feel more at home in our offices and to learn from them what they know.

In operating trucks, miscellaneous knowledge is useful. Only one type of trailer was on the market two years ago when a certain company, in opening the eastern district, sent me a circular advertising a new type which it was about to market. Its advantages immediately appealed to me and, after getting into communication with the company, we installed one of the

machines under a 60 to 90-day guarantee on the representative's own suggestion; but we bought it outright within 10 days.

As another interesting example, a commodity which some years ago sold as an accessory for motor-vehicle operation was represented as accomplishing great savings on engine maintenance and the like. I analyzed those savings with the sales representative in relation to ordinary fleet-operation and found that, if we installed this product, it would cost $44 per year for each unit of this device that was put into service in the field.

Preventive maintenance is my message as applied to the many problems arising each day among the individuals who operate motor-trucks, and it is hoped that these brief suggestions may serve to solve a few of the many common yet complex problems of the fleet supervisor.

THE DISCUSSION

T. L. PREBLE[2]:—Although my present position in the automotive industry is of a nature having to do with many different departments of the business, my duties for a number of years were confined largely to the important, but inadequately recognized, function of maintenance. Recently asked by a friend why I consented, with obvious enthusiasm, to take an active part in the Maintenance Session of the 1929 Transportation Meeting, I replied that in my opinion automotive maintenance is a factor of tremendous importance to the industry; that its possibilities are unlimited; that many high executives, although they occasionally offer to the maintenance department the meaningless lip-service of a few high-sounding generalities, are not themselves sufficiently posted to appreciate these possibilities fully. Such men will be well repaid if they will devote a portion of their time to an intensive study of this problem. Progress has been made, but there is still a long road ahead.


F. K. GLYNN

Maintenance Technique Needs Further Development

The nature of the automotive industry and its phenomenally rapid expansion have necessitated the development of a tehnique of maintenance different in many respects and more highly specialized than the servicing ordinarily provided for mechanical products. In the early development of highway transportation, no maintenance problem existed that is comparable with that which exists today following the development of the internal-combustion engine and the modern automotive vehicle. Motor-vehicles are expensive, quick-wearing machines; hence their servicing has become a very important consideration involving, as it does in this Country alone, a mechanical force of nearly 500,000 repairmen and an annual expenditure for maintenance of many hundreds of millions of dollars. Automotive maintenance is, in fact, a lusty infant-industry and one that is rapidly emerging from its swaddling clothes and becoming a real personality in the automotive family.

The application of scientific methods to production and engineering has been the recipient of much profitable discussion. It is gratifying to observe that, whereas there is still much of the old-time "grease-ball," "necessary-evil" habit of mind to be eradicated, *there are definite and plentiful indications of the engineering approach to maintenance problems.* I believe this to be the keynote which shall underlie the future progress in maintenance methods. I hold that this trend toward an increasing dignity and a more completely recognized importance of automotive maintenance will prove to be of inestimable value. With the approach of comparative saturation of the vehicle-manufacturers' market and of the increasingly severe competition which confronts the manufacturer and the owner alike, maintenance will many times be the deciding factor between success and failure. Maintenance is coming into its own!

Mr. Moxey is a man who knows his job; one whose paper has been written from his broad and intensive experience. He expresses the viewpoint of a careful student and an eminently practical man.

Engineering and Service Relationships

Two important departments of the motor-vehicle manufacturers' establishment exist, the functions of which are or should be closely interrelated yet which all too frequently are found to be at swords' points. They have a common goal, which is the enhancement of the owner's investment by the prolongation of its profitable life.

In considering the engineering department and the service department in their relations to each other and to their real boss, the customer, we sometimes find an engineer whose motto seems to be "Design 'em and forget 'em," and whose specifications, when they reach the service man in the field, are greeted by the dismal groan, "Read 'em and weep." We also find the service man who sneers at what he calls "them theoretical high-hat engineers" and who boasts, "I'm a *practical* man!" Between these poorly meshed cogs of the manufacturers' machine, we frequently find that the innocent bystander, the customer, bears the brunt of the frictional loss.

This involved problem is ably discussed in the paper by E. D. Sirrine entitled, Engineering and Service Relationships in the Truck Industry[3]. In addition to his background of experience, I believe him to be peculiarly fitted to discuss this subject because of his ability to pick the wheat from the chaff and to point the way

[2] M.S.A.E.—Assistant general manager, Brockway Motor Truck Corp., New York City. Mr. Preble was scheduled as Chairman of the Maintenance Session but was unavoidably absent. His remarks, as printed herewith, were intended to be introductory to Mr. Moxey's and Mr. Sirrine's papers; they were read at the meeting by F. K. Glynn, acting chairman.

[3] See S.A.E. JOURNAL, December, 1929, p. 630.

constructively to an improvement which is badly needed in many companies.

Collusion Among Employes Debated

H. V. MIDDLEWORTH[4]:—We have had considerable trouble with our inspector, mechanics and mechanics' helpers in that our inspector has reported work which he said must be done and which was found later to be of little consequence. In other words, we found that there was collusion among these men so that they could make unnecessary overtime. Has Mr. Moxey experienced similar trouble?

J. G. MOXEY:—We do not pay a driver for overtime. The driver and the mechanic never get together. The shops are run as maintenance depots and service-repair depots, not as service depots. The drivers and the inspector make the repairs to the trucks on their regular time, with no overtime, and they are supposed to use their own good judgment in getting the vehicle back into service.

Per-Vehicle Investment in Parts Stock

ACTING CHAIRMAN F. K. GLYNN[5]:—We have in attendance here a man who operates a large fleet and who averages between $10 and $15 per vehicle in value of stock parts in his stockroom. His arrangement with manufacturers is that parts shall be available at any time during the 24-hr. day and, for this reason, it is unnecessary for this operator to carry a heavy investment in parts on the shelves of his stockroom. As nearly as various fleet-operators have been able to calculate, it costs about 10 per cent of the investment to carry a stock of parts. What has been your experience, Mr. Moxey, regarding the amount of stocked parts that it is necessary to carry?

A. J. SCAIFE

MR. MOXEY:—Because we use field shops it is seldom that the local shop is near a manufacturer's parts depot, therefore we are compelled to carry a somewhat larger stock on the shelves than it is necessary to carry otherwise. If the shop and the parts depot are in the same city, the distance between the two may be considerable and the parts manufacturer will not, in general, furnish delivery service. Therefore it is necessary to charge back into the stock overhead the cost of transference to the shop as well as that to the field.

The figures I quoted were specified as representing the total stock investment, including not only manufacturers' parts but all other units of a truck such as assemblies, bodies and the like. Our investment for parts is about $62 per vehicle, including the entire unit-assemblies carried for the maintenance of the vehicles. We have never calculated the exact number of small parts per vehicle that it is necessary to stock.

ACTING CHAIRMAN GLYNN:—Why is it that manufacturers' service-stations will not deliver parts to the operator? One operator may be forced to send a truck across a city to obtain parts, and his next-door neighbor may need to do likewise; whereas the parts service-station could deliver to several service stations on one trip with one truck. Therefore, should we not consider a service charge for the service station to deliver parts and have the service station deliver them?

A. W. KENERSON[6]:—In most instances the manufacturers' service-department, to which reference has been made, has a truck whose operations are confined to freight and express pick-up. My suggestion is that the policy of the manufacturer be changed to permit this truck to make deliveries which, in many instances, could be made on the same trip en route to the freight or express office. I believe that this would not present a very serious problem for the manufacturer to solve.

A. J. SCAIFE[7]:—I can see no reason why an operator should carry a large stock of parts unless the manufacturer of any particular part has no parts depot in that city. In my opinion, the necessity for carrying a large stock of parts is eliminated where the manufacturers have service stations in the same cities in which the operator has shops.

ACTING CHAIRMAN GLYNN:—I agree with Mr. Scaife, except that I believe there is a middle ground that will work out to the advantage of both the operator and the service station.

PIERRE SCHON[8]: — The delivery of parts from the manufacturer's branch constitutes only a minor portion of a parts transaction. Correct ordering of the parts is more important than the delivery. In most cases we find that when a mechanic is working on a rush job in a fleet operator's garage, worn parts are often taken to the parts department and the correct replacement parts are immediately obtained. In that way the customer gets quicker action than by telephoning for the parts and waiting for the seller's delivery truck to deliver them to his garage. If the service station or the manufacturer's branch retail-store were expected to make delivery of all parts sold, almost all of the parts orders would come in by telephone and, consequently, many chances for errors in specifying correct part-numbers would occur. In the customer's garage it may also take more time for the mechanic or stock clerk to look up the correct parts-numbers in the catalog and transmit the information by telephone to the parts department than to send a helper over to the store and get the parts needed for a rush job. Additional loss of time would be caused by asking the parts department to deliver the parts to the customer's place of business, as the buyer in such case would be forced to wait his turn, the seller's delivery truck being expected to serve a large number of customers.

MR. MOXEY:—On an overhaul job or reconditioning of a service unit, we have found it essential to make up a complete list of needed parts for the parts depot and submit it, going the next day for the delivery of the parts. Otherwise, the operator's representative is

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[4] M.S.A.E.—Superintendent of operations, transportation department, Consolidated Gas Co. of New York, New York City.

[5] M.S.A.E.—Engineer, operation and maintenance of automotive equipment, American Telephone & Telegraph Co., New York City.

[6] Manager, automotive equipment department, Standard Oil Co., of Ohio, Cleveland.

[7] M.S.A.E.—Consulting field engineer, White Motor Co., Cleveland.

[8] A.S.A.E.—Sales engineer, General Motors Truck Co., Pontiac, Mich.

greatly delayed in obtaining the needed parts over the counter. For say one part, the mechanic might go to the parts depot and exchange it over the counter; but, in general, when parts are obtained in quantities, we attempt to forecast what our overhaul problem will mean to the manufacturer and to find out what a definite plan of feeding the needed parts into our shop will mean. We have attempted to familiarize our drivers with the vehicles to the highest possible degree so that, when something goes wrong with their vehicles, they can pick out the needed parts from the parts catalog.

Final Chassis-Record Forms Cited

ACTING CHAIRMAN GLYNN:—An S.A.E. committee of which J. F. Winchester is Chairman is engaged in devising a specification sheet or Final Chassis-Record Form for truck and motorcoach chassis so that, when a manufacturer delivers a vehicle to the fleet operator, this Final Chassis Record will accompany the vehicle and give the operator the essential information for the ordering of the parts and the like.

MR. MOXEY:—Why should we, as operators, assume the responsibility which is already that of the manufacturer? I claim that all that should be necessary is to furnish the manufacturer with the number and name of the part and with the serial number of the vehicle.

ACTING CHAIRMAN GLYNN:—I thoroughly concur with Mr. Moxey and believe that any parts station which is not arranged so that it can deliver a correct part certainly should take stock of itself. I believe also that it is essential for parts stations to make a survey from time to time of the number of vehicles in their territory so that they can arrange their stock of parts to meet the needs of the operators. This has been done in some territories.

PIERRE SCHON

Demands on Manufacturer Too Great

MR. MOXEY:—I hope we do not go too far with this matter. Undoubtedly the manufacturer has a responsibility. We do not have as much trouble with the truck owners as with the motorcoach owners. It seems as though the motorcoach operators expect the manufacturers to do everything except collect the fare, and I think that they expect too much in regard to putting the burden of their operation on the manufacturers. The manufacturer has a big problem to construct a vehicle that will continue to run and give the kind of service the operators want. When the manufacturer must do the operators' bookkeeping and attend to other matters for them also, that is asking too much.

Some things that are required of the manufacturer by the operator are unreasonable because of changes that are made on equipment after the equipment is in service and of which the manufacturer has no information. Such changes are in the line of different gear-ratios, sizes and types of wheel and the like, of which the factory has no record. It will be a big problem to try to follow that out and make the distributors and dealers responsible for keeping all such records uptodate.

Providing Money for New Trucks

B. H. EATON[9]:—In following a program that does not schedule a truck for replacement at the end of any definite period, how does Mr. Moxey's company obtain the money for buying new trucks?

MR. MOXEY:—We do not, as a rule, retire trucks. The budgeting of the funds for carrying on the increased business is cared for in, say, November for the succeeding year, and is based on the estimates furnished by the sales organization regarding the business that it is reasonable to expect in the different districts. From that information we calculate the number and sizes of truck necessary in each specified district and budget the necessary funds for purchasing them when that time arrives.

The retirement of a truck is determined by a special budget allowance approved by the board of directors, but the board has never yet seen fit to exercise this power because the justification of the retirement of units of the fleet has been based on a percentage return on the capital investment, which is considerably below the return expected by the directors for the capital expenditure.

MR. EATON:—Over what period do you depreciate the investment in a vehicle?

MR. MOXEY:—We depreciate our vehicles on the basis of 25 per cent per year on the original investment; that is, considering the vehicle as it stands, including full equipment. At the end of four years the vehicle is "off the books."

ACTING CHAIRMAN GLYNN:—With a delivery unit such as you operate, is obsolescence as important a factor as in motorcoach transportation, where the public demands the latest type of equipment?

MR. MOXEY:—Yes. We do retire passenger-cars, but this is on account of psychological reasons rather than from economic considerations. This is at the end of a period after which the car is too much out of date.

J. M. ORR[10]:—What is your company doing to offset the increased registration fees for trucks on solid tires that will be in effect on Jan. 1, 1930?

MR. MOXEY:—Considering a 2-ton vehicle under the Pennsylvania Registration Act, there is a saving of $15 on the air-core and $30 on the pneumatic tire as compared with solid tires. Members of our organization commonly expect that the majority of the vehicles assigned to specific activities cannot logically be put on pneumatic tires. So far as the tire manufacturers are concerned, the air-core-tire problem was unsolved up to several years ago. Only within recent years have they been able to build a tire of the air-core type that could withstand the service and give the organization which used it a just return per dollar invested. We anticipated this change and began replacing such tires as would normally be replaced prior to Jan. 1 to take advantage of the $15 difference.

[9] M.S.A.E.—Motor-vehicle supervisor, Bell Telephone Co. of Pennsylvania, Pittsburgh.

[10] A.S.A.E.—General manager, Equitable Auto Co., Pittsburgh.

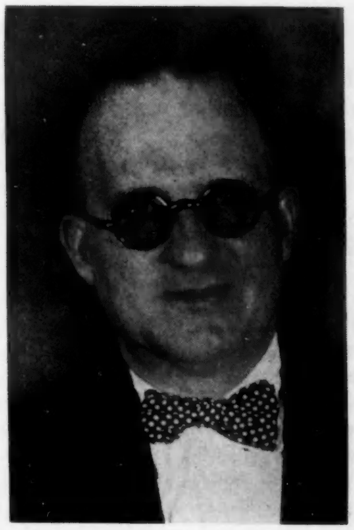
H. C. MARBLE[11]:—I think it is obvious that it is absolutely essential to maintain a proper stock of parts in places where they are readily accessible to the fleet owner. That is what we are striving to do. The difference between having on hand the right part for an automobile or a truck when it is required and going into the average store for the purchase of an article is that, in the latter case, the customer does not feel quite as badly about its not being there and can either go somewhere else to get it or if necessary can generally wait without a great deal of inconvenience.

Availability of Repair Parts Essential

In the case of repair parts, it is essential that they be in stock, and our organization makes every attempt to have them. We have tried many methods of analyzing the parts requirements of the trucks that are in operation in given districts from past experience, as far as distribution or sale of parts is concerned, based on all information we have at our home office. After studying the problem, we have come to the conclusion that the best way is by minimum and maximum requirements.

The fact that always comes to my mind when the question of parts not being on hand is brought up is that, while we are shipping out of headquarters in Cleveland an average of approximately 450,000 parts per week, the total number of parts we are short averages somewhere in the neighborhood of 3000 or 4000. The percentage of shortage to parts shipped out is very small but, unfortunately, it is just those few that cause continual trouble and all these vexing delays.

Hardly any matter comes to us which receives greater attention than parts shortage. The rule is that when parts are short the service department gets them ahead of production. We have in many cases held up truck production to supply service parts; in fact, we do everything we possibly can to maintain stocks of service parts. We recognize the importance of the job and want all of the criticisms and suggestions we can get from everyone along that line.



H. C. MARBLE

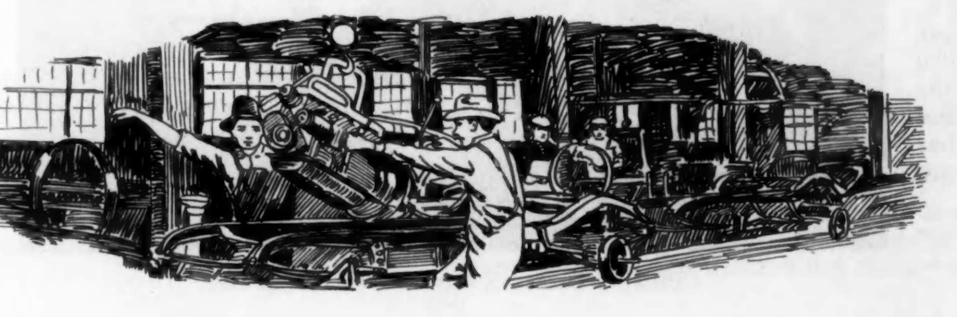
Shall Factory Branches Deliver Parts?

ACTING CHAIRMAN GLYNN:—Mr. Moxey and others mentioned that the fleet operator is compelled to maintain a service car, and the fact was pointed out that four or five fleet operators maintaining garages close together in a neighborhood are each compelled to send a service car to the manufacturer's service station to secure parts perhaps several times a week. The question is, Why should not the parts department of the factory branch deliver parts, possibly once each day, as ordered by the fleet operators? Why are we obliged to go after parts?

MR. MARBLE:—The question of delivery of parts has been considered by the manufacturer a great many times, I think, but so far it has ended with the idea that, if delivery of parts were made by the manufacturer who has branches, a demand would be made that dealers also make delivery. Such service naturally costs something, whether the delivering is done by the seller or the buyer calls for the parts. We have investigated along several different lines and found that, even if we were to deliver parts, in most cases the fleet owner would still be required to maintain his service truck for his own particular business. His truck not only calls at our service station but at many other places and is used for many other purposes; the calling for parts is incidental in many instances to another trip or is part of it. Moreover, if we should attempt to make delivery of parts say once or twice a day, or at some stated period, a demand would immediately follow for special rush deliveries which would cost more than the scheduled delivery.

The manufacturer is open to conviction as to what the customer really wants, and I believe that the best way to get to the bottom of it would be for the manufacturer and his customers to assemble figures showing just what delivery costs are and ascertain whether the cost under the present method can be reduced by having the factory branch deliver the parts. I know that the manufacturer is interested in reducing the cost of maintaining motor-trucks and, if this is one way of doing it, I am sure that the manufacturer is willing to be convinced. I should like to get statistics on such costs.

[11] A.S.A.E.—Vice-president in charge of service, White Motor Co., Cleveland.



A Diesel Engine in an Automobile

By C. L. Cummins[1]

Milwaukee Section Narrative *Illustrated with* Photograph

WE MANUFACTURE a 4½ x 6-in. four-cylinder Diesel engine the size of which is near enough to that of an automobile engine to have tempted us to install one of them in an automobile for trial, although its normal speed is only 1000 r.p.m. and the construction is heavy enough to conform to Lloyd specifications.

After considering the question for a year, we decided to make the trial and were able to place the engine in the chassis of a Packard eight-cylinder car with no change in the hood or any major parts of the car. Because of the low speed of the engine, it was necessary to change the original gear-ratio of nearly 5:1 to 2.5:1. The engine is such a close fit in the space available that it clears the radiator by only ⅜ in. and no room is available for a radiator fan. It was impossible to put the engine in place without removing the steering-gear, or to install the steering-gear after the engine was in place. The only solution we found was to hoist the car and lower it over the engine.

Another difficulty that developed was in securing a license for the car. No provision was made on the application blank for cars other than gasoline, steam and electric. The local licensing official could not be persuaded to alter the form until she had secured advice from Indianapolis, but finally the license was secured by sustituting "Diesel" for "gasoline" on the blank.

The car weighs 6000 lb. and is fitted with 34x7-in. balloon tires. At the start, the top speed was approximately 55 m.p.h., but the governor and throttling mechanism have limbered up a little since and now cut off at about 50 m.p.h. The performance on the road compares very favorably with that of the engine which was removed. The car has been driven about 4000 miles with the new engine, and no trouble has developed except from frozen water at a low point in the fuel line and some wiring trouble caused by interference with the circuit of an auxiliary battery. A 12-volt motor-generator is used for starting. The engine is cranked at a speed of approximately 150 r.p.m. with the compression relieved and takes up its cycle when the reliefs are closed and the fuel is supplied.

Interesting light is thrown on the question of cooling by the facts that no trouble has been experienced because of the lack of a radiator fan and that we have been unable to get heat inside the car either by a blower at the dash, delivering air from a jacket surrounding the entire exhaust line, or by a water heater. On our present trip between Columbus, Ind., and Chicago, the water attained a temperature of 100 deg. fahr. after we had covered one-third of the radiator, but it became cooler as we came further north. Finally we covered the entire radiator, and the water circulated at a temperature of about 90 deg.

Fuel Averaged 0.28 Cent per Mile

On the trip to New York City I drove fairly carefully over the straight, level roads from Indianapolis to Columbus, Ohio, going as fast as 40 m.p.h. only once or twice, and the fuel consumption was at the rate of about 35 miles per gallon. From there to Harrisburg, Pa., especially the 385 miles from Zanesville, Ohio, our fuel consumption was higher because of detours, snow, ice and mud, but the car went through the mountains almost as quickly as any car having a gasoline engine. Over the same road, I made very little higher average speed in a LaSalle.

The entire trip from Indianapolis to New York City was made at an average speed of 31½ m.p.h., the total fuel consumption was 30 gal., and it cost us $1.38. The fuel was bought at two prices, one as low as any at which it can be bought and the (*Concl. on p.* 521)

Cummins Diesel Engine Installed in Car

[1] A.S.A.E. — President, general manager, Cummins Engine Co., Columbus, Ind.

Measurement of Comfort in Automobile Riding

By F. A. Moss, M. D.[1]

ANNUAL MEETING PAPER *Illustrated with* PHOTOGRAPHS, DRAWINGS AND CHARTS

EXPERIMENTS that have been in progress since the 1929 Semi-Annual Meeting to measure the fatigue caused by an automobile ride, using the human body as a measuring instrument, and to predict therefrom the possible effects of various types of spring-suspension, shock-absorber and other comfort-giving components are described. Initially, the problem was approached from the physiological standpoint because fatigue is definitely known to be a physiological phenomenon and, if the physiological changes are sufficiently marked to be measured, physiological tests are definite and quantitative.

Changes in the human body are a good index of relative comfort, and, if the normal reactions of an individual or any group of individuals before a test are known, similar measurements at the end of a test or at the end of an automobile ride should show an appreciable difference. This difference, which the author claims is a direct measure of comfort, can be determined by measuring physical and nervous fatigue. For measuring the latter, number checking, speed of reaction, mental multiplication, steadiness of the hand and basal-metabolism rate tests were given; and, for the former, equilibrium tests using a wabblemeter were employed. Descriptions of various types of wabblemeter are included, and the results of the nervous-fatigue tests are presented.

Plans for future development and study include (*a*) further improvement and standardization of two types of wabblemeter, (*b*) further standardization of the basal-metabolism test with particular attention to establishing a normal for different times of day, (*c*) improvement of the score card for reporting discomfort after the riding tests and (*d*) experiments with other new measuring devices. Further experimentation will include (*a*) investigation and application of tests to subjects in the laboratory, (*b*) study of tests on a large number of taxicab and motorcoach drivers and (*c*) application of the results with various outside groups of riders and test persons.

In the discussion the extraordinary importance and great value of the investigation was stressed. Much work remains to be done, according to the various speakers, some of whom suggested future tests.

SINCE the invention of the first automobile, manufacturers have been studying ways and means of improving its riding-quality. Various types of spring, cushion and shock-absorber have been devised and tried, only to be replaced in time by what seemed to be an improved comfort-giving device. Considerable blind-trial-and-error experimenting has characterized this search for devices that would assure a pleasant ride. The result has been an immense waste, with millions of dollars put into the manufacture of what proved to be unsatisfactory equipment.

Fatigue-Measuring Instruments Essential

The reason for this waste has been the lack of objective recording-devices by which the degree of comfort could be measured. In the absence of such measurement, the research engineers had to depend very largely on the subjective hunches of those who rode in automobiles. They have been in a position similar to that of the physician who was called in to treat a fever patient before the invention of the clinical thermometer. The patient could tell the physician that he felt hot and the physician could conclude that he had a fever, but, without the aid of the thermometer, neither the physician nor the patient could tell how hot or how much fever. Even so, the automobile engineer, when he questions a passenger who has been riding for a given length of time in a machine, learns that the passenger is somewhat uncomfortable and feels fatigued, but without the aid of an objective measuring-device neither the engineer nor the passenger is able to tell how uncomfortable or how much fatigued. This study was undertaken with the hope of providing such a measuring instrument.

If we wish to know how much worse lobar pneumonia is than a common cold we could find out by taking the temperature, counting the pulse and making a blood analysis of patients suffering from these conditions. If we would know how the Dodge car of 1920 compares in riding-quality with the 1930 model we can find our answer by taking a group of people, and, having subjected them to similar riding-conditions in the two cars, measuring the changes produced in the passengers by each ride. This is what we intended to do, and we began by studying the physiological changes in fatigue. Fatigue is much easier to measure than comfort, but a very close relation exists between the two, and if we measure one we are indirectly measuring the other. As fatigue increases, comfort tends to decrease; in other words, comfort seems to be inversely proportional to fatigue.

Physiological Tests of Fatigue

We had two reasons for initially approaching the problem from the physiological standpoint. First, we know definitely that fatigue is a physiological phenome-

[1] Head of the department of psychology, George Washington University, City of Washington.

non, and, second, if the physiological changes are sufficiently marked to be measured, physiological tests are very definite and quantitative. Our investigation of physiological tests consisted in a preliminary study of the tests with known muscular fatigue produced by riding a bicycle ergometer; then their application to automobile riding. This part of our investigation was given in a Preliminary Report on Fatigue Produced by Automobile Riding[2].

The physiological tests with which we experimented included: blood pressure, pulse, carbon-dioxide combining-power of the blood, blood sugar, hemoglobin, blood counts, metabolism and respiration, chemical and microscopic urine analyses, chest expansion, strength of grip and electrocardiograph records (See Fig. 1). All the tests were tried in the preliminary study of severe fatigue and those giving sufficiently sensitive differentiation between normal and fatigue conditions were applied on road trips after driving.

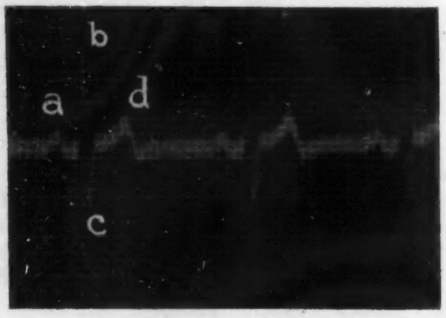


FIG. 1—ELECTROCARDIOGRAPH RECORD SHOWING MOVEMENTS OF GALVANOMETER STRING DURING HEART ACTION

Auricular Contraction Begins at *a* and Finishes near *b*. The Sweep of Excitation over the Ventricles Is Represented by the Wave *bc*, and the *d* Wave Occurs at the Latter Part of the Ventricular Contraction When the Blood Is Being Expelled into the Large Arteries

As indicated by this part of the study, excellent measures of marked muscular fatigue can be obtained by using these physiological tests. The majority of them, however, are not so applicable to the less strenuous fatigue of riding. For fatigue of riding, most promise was offered by the test of carbon-dioxide combining-power of the blood and the basal-metabolism test; the first measuring the ability of the blood to take up and transport to the lungs the waste product of carbon dioxide, and the second measuring the individual's rate of consumption of oxygen with the apparatus shown in Fig. 2. Extensive use of the first has been questioned on the ground of difficulty of application. The latter we have retained in our later studies and expect to standardize further.

The Nerve-Fatigue Tests

Comparison of the physiological results obtained in the riding experiments with those obtained in the preliminary studies of muscular fatigue indicates that riding fatigue does not represent a very marked muscular fatique, and suggests that it may represent a condition more closely similar to nerve fatigue. Physiologists and psychologists have claimed that actual nerve fatigue does not exist but that all fatigue is in reality muscular. In conducting impulses, nerves actually undergo considerable diminution in tissue substance, as has recently been demonstrated in the physiological laboratory, and under conditions of exercise they show chemical and energy changes very similar to those shown in a fatigued muscle.

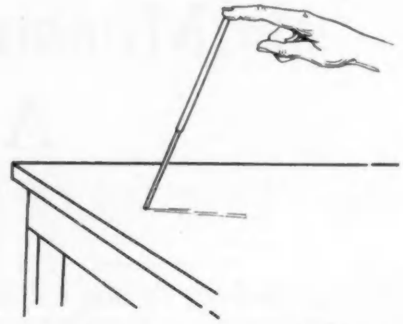


FIG. 3—APPARATUS FOR TESTING STEADINESS OF THE HAND

This Was Devised by Dr. H. C. Dickinson, of the Bureau of Standards, and Consists of Two Small Metal Tubes, One Sliding within the Other, and Measures Steadiness by the Subject's Ability To Hold the Device against a Table When the Inside Tube Is Drawn Part Way Out Without Sliding This Tube into the Other

With these facts in mind, this part of the investigation of measurements of riding fatigue has been a rather extensive study of various tests of nerve fatigue. The initial step in the study of these tests has been the establishing of normals for each subject on each of the tests, which was done by practising the test until the increase in performance due to learning was eliminated. As with the study of physiological tests and muscular fatigue, the first step has been a preliminary study of the tests as applied to fatigue produced in the laboratory, with a subsequent application to automobile-riding fatigue.

For the preliminary part of this portion of the study, a condition of nerve fatigue was produced by a 5-hr. continuous mental multiplication. This consisted in multiplying two-place by two-place numbers, the problems being arranged in sets of 40. As soon as a set was finished, the subjects were instructed to begin another set immediately. At the end of 5 hr. the various tests[3] were applied. Road tests of the measurements of nerve fatigue consisted in their application after periods of automobile riding. The results obtained in both series are given below.

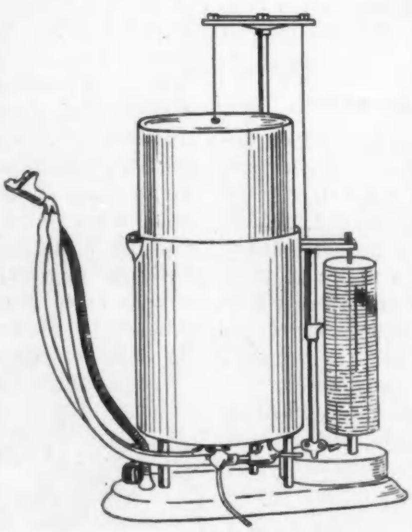


FIG. 2—BASAL-METABOLISM MACHINE

Number Checking.—After fatigue by mental multiplication, the average decrease was 2.5 per cent. Riding fatigue produced a decrease of 2.3 to 16.9 per cent, depending upon the conditions of the trip as to distance and the type and condition of the car used, an 8-hr. ride over a very rough dirt and gravel road giving the latter figure. The results in number checking are very constant, virtually no exceptions being found to the indication of a decrease in performance with the fatigue. Another interesting fact about the results is that those who had done the major part of the driving on the trips showed the largest decrease.

Speed of Reaction.—Speed of reaction in tapping a telegraph key showed a decrease of 6.9 per cent after mental multiplication, 11.5 per cent after a 300-mile drive and 6.3 per cent after 150 miles over a poor road.

[2] See S.A.E. JOURNAL, September, 1929, p. 298.

[3] For details of the various tests see S.A.E. JOURNAL, September, 1929, pp. 302 and 303.

Mental Multiplication.—Mental multiplication after driving showed an average decrease of 19.4 per cent in speed and an average decrease of 18 per cent in number of problems correctly solved per unit time. Without exception, all the subjects showed decrease in multiplying ability after the road tests.

Steadiness of Hand.—Two methods of measuring steadiness have been considered. The first consisted in measuring by an apparatus constructed so that the individual was required to trace through a narrow groove with a stylus without touching the edges[4]. The second type of apparatus consisted of two small metal tubes, one sliding within the other. Steadiness is measured by the subject's ability to hold this, when the inside tube is drawn part way out, against a table, without sliding the inner tube into the outer. The apparatus for these two tests was devised by Dr. H. C. Dickinson, of the Bureau of Standards, and that for the latter is

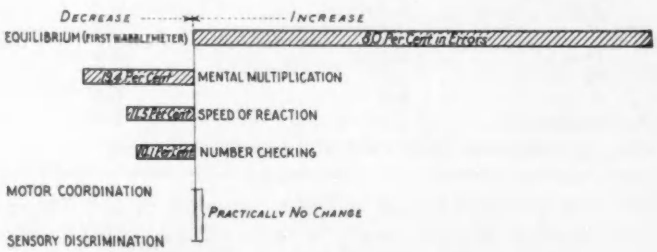


FIG. 4—SUMMARY OF NERVE-FATIGUE TESTS APPLIED TO MEASUREMENT OF RIDING-COMFORT

shown in Fig. 3. Results on these two tests are not conclusive. More preliminary practice before application and further trial are necessary before a conclusion regarding them can be reached.

Basal Metabolism.—The basal-metabolism rate or the rate of oxygen consumption has shown a constant increase after road trips, varying from 7 to 33 per cent, both averages depending upon length of the trip, type of car used and type of road traveled. The lowest average increase was obtained after a half-day's ride over a good road, and the highest average increase after a 150-mile ride over a very bad road.

On the whole, the investigation of tests of the type just described gave us much more encouragement in the problem of measuring automobile fatigue than was given by the purely physiological tests. A summary of results is presented in Fig. 4.

Tests of Equilibrium

One effect of long automobile riding that is generally recognized among automotive engineers is a tendency to impair one's equilibrium. Acting on recognition of this condition, an attempt was made to devise a machine that would indicate the amount of disturbance a subject's equilibrium has undergone. A series of four different wabblemeters have been constructed and tried. The later developments of these have been retained and perfected for giving an accurate and sensitive indication of fatigue.

The first of the series was a very crude machine[5] used to measure the ability to balance on one's heels for a given time. This wabblemeter showed increase in contacts for all subjects and very great differences between normal and fatigued condition. The subsequently described machines have replaced this one because of greater constancy in the machine itself and greater ease in equalizing conditions for each subject. This first one depends too greatly upon the exact position of the feet and the type of shoe worn.

The second wabblemeter, shown in Fig. 5, consists of a platform balanced on a universal-joint. The metal rods projecting from the front corners of the platform make contacts with a metal bar if the platform is moved too far either up or down. The contacts complete an electrical circuit so that each contact is indicated by a bell or counter. Experimentation indicated the practicability of developing a perfected platform-balance wabblemeter. All of our subsequent machines have been built upon this idea.

Adopting the idea of the second wabblemeter, two new machines were independently constructed, one of these, which is shown in Fig. 6, being devised by Dr. Dickinson. This machine consists of a platform mounted on a joint similar to the universal-joint used in the wabblemeter just described. Loss of balance is measured in two ways; first, by the number of contacts made when the platform is moved enough to touch the mental projections from the base of the machine at the four corners, the contact, as in the previously described machine, being measured by a bell or electric counter; and, second, by the quantity of fluid pumped through the machine. At each of the four corners of the machine, a piston-like arrangement pumps fluid through every time the platform is moved or put out of balance, and this fluid is collected and measured in a graduated tube. Such a method of measuring the wabble enables us to get a measure of the loss of balance even though it is too small to be recorded in an actual contact or to

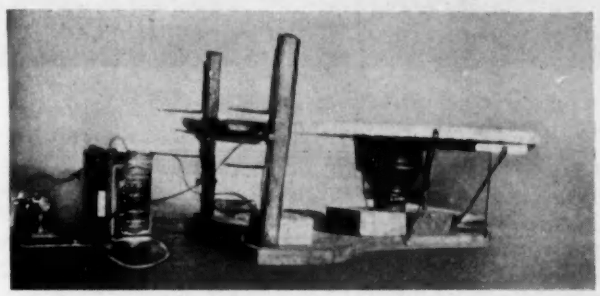


FIG. 5—ONE OF THE WABBLEMETERS USED IN THE TESTS

In This Instrument the Platform on Which the Subject Stands Is Mounted on a Universal-Joint. If This Platform Is Moved Too Far in Either Direction, the Metal Rods That Project from the Front Corners Make Contact with a Metal Bar, Thus Completing an Electric Circuit That Registers Each Contact

register on the bell or counter. This machine is easily used and has given very practical results.

The fourth of the series of wabblemeters, shown in Fig. 7, is designed to give a graphic record of each wabble or bodily sway. The individual taking the tests stands on a platform, *e*, mounted on a ball-and-socket joint. The movements of this platform as the individual stands on it are recorded by pens registering on a revolving drum, *f*, timed to make a complete revolution in a given time. A perfect record, or no movements of the platform, produces a straight line on the chart,

[4] For a description of this test and the apparatus used see S.A.E. JOURNAL, September, 1929, pp. 302 and 303.

[5] For an illustrated description of this instrument see S.A.E. JOURNAL, September, 1929, p. 303.

and wabbles are recorded as deviations or ups and downs from this straight line. Normal records may be practically straight lines or show some slight deviations; fatigue records show a larger number of deviations in the record line, in some instances almost continuous deviation first in one direction and then in the other. This type of wabblemeter is the most desirable from the standpoint of giving a permanent and detailed graphic record of each test.

The results of a wabblemeter test after a typical 8-hr. drive are given in Table 1.

Study of Adrenalin Effects

In comparing the physiological results in our first preliminary experiment using the severe fatigue of the bicycle ergometer with the fatigue of automobile riding, the question naturally comes to mind, why do the physiological tests show so much less change after automobile riding, though the subjective and external signs of fatigue may be very great and the effects of long duration? A likely explanation of the lessened manifestations when fatigue is produced over a long time is that certain physiological products are poured forth into the body to counteract some of the fatigue products. We were therefore led to investigate one known natural bodily counteractant to fatigue. Adrenalin, the active principle of the adrenal glands, is generally recognized as having such effects in respect to fatigue.

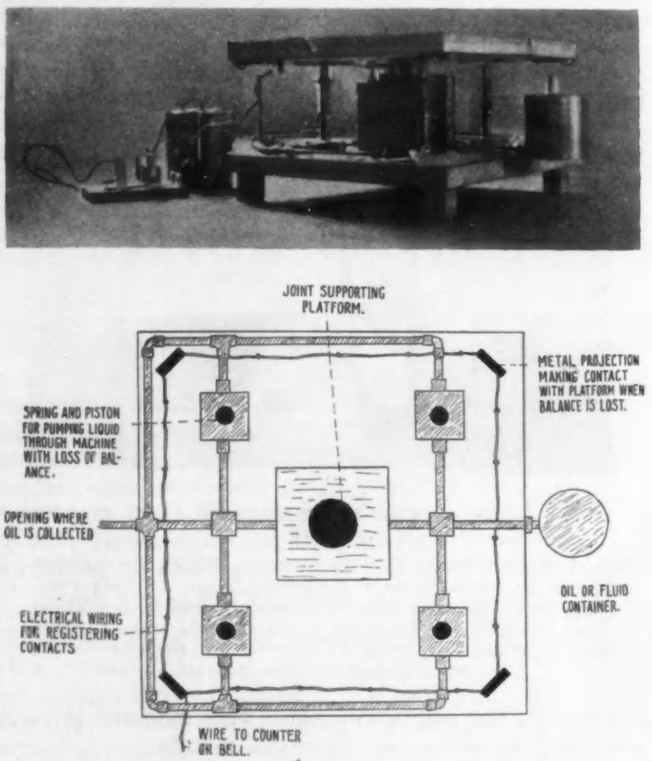


FIG. 6—ANOTHER TYPE OF WABBLEMETER

This Was Devised by Dr. Dickinson and Consists of a Platform Mounted on a Universal-Joint Similar to That Used in the Instrument Illustrated in Fig. 5. Loss of Balance Is Measured Either by the Number of Contacts Made When the Platform Is Moved Far Enough To Touch the Metal Projections at the Corners of the Machine, the Contacts Being Indicated by a Bell or a Counter, or by the Quantity of Fluid Pumped through the Machine. The Latter Method Enables Any Loss of Balance, No Matter How Slight, To Be Measured. The Plan of the Instrument Is Shown in the Drawing Underneath

An experiment was undertaken in an effort to find out what effect the administration of adrenalin has upon the physiological manifestations after strenuous exercise over a short time and to compare the physiological manifestations of fatigue when adrenalin was and was not administered.

The experiment was carried out on 5 of the 10 subjects who had taken the other tests. On the morning

TABLE 1—RESULTS OF A WABBLEMETER TEST AFTER A TYPICAL 8-HR. RIDE

Subjects	Wabblemeter Errors: Averages of Last Two Trials in Preliminary Practice before Ride	Wabblemeter Errors: Averages of Three Trials after 8-Hr. Ride
A	5.0	26.3
B	9.5	16.5
C	3.5	12.0
D	2.5	3.7
E	0.0	6.3
F	1.5	4.3
G	2.0	3.0
H	1.0	11.3
I	0.0	0.5
Averages	2.8	9.3

Average Increase in Errors, 232 Per Cent

of the experiment, each subject reported to the laboratory without having eaten. A normal test before exercise was made on each subject for blood pressure, carbon-dioxide combining-power of the blood, blood sugar, leucocyte count, metabolism and chemical and microscopic urinalysis. Each of the five men was then subjected to strenuous exercise for 15 min. on the bicycle ergometer. Five minutes before exercise each subject was given 2 cc. of adrenalin chloride of a strength of 1 to 10,000. This was injected into the muscles of the legs, 1 cc. being injected into each leg. After the 15-min. exercise, the physiological tests already mentioned were again made, with the following results:

Blood Pressure.—For four of the subjects both systolic and diastolic pressure were measured at the beginning of the exercise and at the end. Blood-pressure readings were also made at 1-min. intervals during the 15-min. exercise-period.

After the exercise the systolic pressure increased and the diastolic decreased in all cases, the averages being 15 and 21 per cent respectively. When no adrenalin was given, these values for the same subjects were 31 and 15 per cent respectively. Blood-pressure curves throughout the exercise period are very similar to those obtained with exercise when no adrenalin is given. In either instance, fatigue causes a rise to the maximum height and a gradual fall, the fall marking the onset of exhaustion. Of significance, perhaps, is the tendency for the height of the curve to be somewhat lower when adrenalin is administered and also the fact that at the end of 15 min. the fall from the height has not been so great with adrenalin. The results seem to show, particularly in reference to systolic pressure, a certain counteractive effect of adrenalin in manifestations of fatigue.

Carbon-Dioxide Combining-Power of Blood.—The results in measuring the carbon-dioxide combining-power of the blood show a 31-per cent decrease with adrenalin as compared with a 42-per cent decrease for the same subjects with no adrenalin. The observation worthy of note is the difference between the decrease in com-

bining power after exercise when the adrenalin was administered and when it was not. In one subject a greater deviation from normal was observed in the adrenalin experiment, but the marked tendency is for greater deviation to occur when no adrenalin is administered.

Blood Sugar.—Blood sugar showed an average, but not constant, increase of 11.8 per cent with and 10.8 per cent without adrenalin. This test was of little differentiating value in either instance. Studies of the properties and physiological action of adrenalin have shown that it stimulates blood-sugar production. However, the utilization of fuel materials is so rapid during the exercise that the actual increase is probably masked.

White-Cell Count.—Three of the subjects showed an extremely marked increase in white blood-cells when no adrenalin was administered. When adrenalin was given the increases were not as marked. The results are not constant enough to be absolutely indicative, although the averages for all subjects point to a decidedly greater physiological change when adrenalin was not administered.

Basal Metabolism.—In every one of the subjects the basal-metabolic rate after exercise was lower when adrenalin was given than when none was administered. The average increase over normal is 50.8 per cent without and only 21.6 per cent with the adrenalin.

Fig. 8 indicates the results of the adrenalin study. Although the results are not absolutely constant in every test applied, the totality of effect is strongly in support of the conclusion that adrenalin has a counteracting effect upon the physiological manifestations of fatigue produced by strenuous exercise of relatively short duration. With the constant production of adrenalin over a period of less strenuous exertion, as in riding, this physiological product conceivably would considerably mask physiological manifestations.

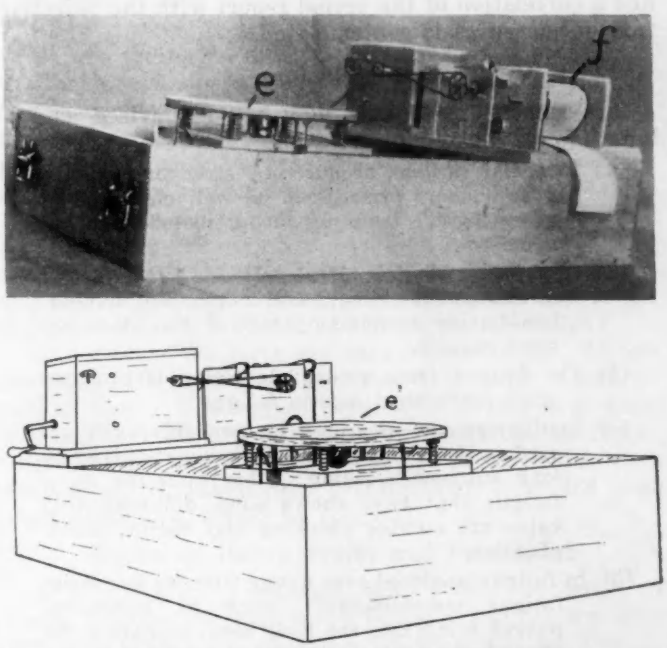


FIG. 7—WABBLEMETER DESIGNED TO GIVE A GRAPHIC RECORD

The Platform *e*, on Which the Subject Stands, Is Mounted on a Ball-and-Socket Joint and the Movements of This Platform Are Recorded by Pens That Register on the Revolving Drum *f*. No Movement of the Platform Gives a Straight Line on the Chart and Wabbles Are Recorded as Deviations from It. This Form of Wabblemeter Is the Most Desirable Since a Permanent and Detailed Graphic Record of Each Test Is Obtained

A list of the tests experimented with in the measurement of fatigue, their relative value, application and other data are given in Table 2.

TABLE 2—TESTS EXPERIMENTED WITH IN MEASUREMENT OF FATIGUE

Name of Test	Type of Fatigue to Which Applicable	Ease of Giving	Method of Giving	Remarks
		Tests Definitely Retained as Valuable		
Basal-Metabolism Rate	Both muscle and nerve	Fairly easy	Individual	Increased with fatigue
Carbon-Dioxide Combining-Power of Blood	Very good for immediate muscle. Further consideration for nerve	Difficult	Individual	Decreased with fatigue
Number Checking	Nerve	Very easy	Group	Increase in errors with fatigue
Balancing on Wabblemeter	Both muscle and nerve	Very easy	Individual	Increase in errors with fatigue
		Tests To be Studied Further		
Systolic and Diastolic Blood-Pressure	Immediate muscle fatigue	Easy	Individual	Systolic rises to height and falls as exhaustion sets in
Blood Sugar	Both (-)	Difficult	Individual	Increase with fatigue
White Blood-Cell Count	Both (-) Very good for muscle	Difficult	Individual	Increase with fatigue
Chemical and Microscopic Urinalysis	Both (-) Good for extreme muscle	Difficult	Individual	Casts and albumin in urine after extreme muscle fatigue
Mental Multiplication	Nerve	Easy	Group	Decrease in speed and increase in errors with fatigue
Speed of Reaction	Nerve	Easy	Individual	Decrease in speed with fatigue
Steadiness	Nerve	Easy	Individual	Decrease in steadiness with fatigue
		Tests Discarded after Experimentation		
Pulse Count	Muscle	Easy	Individual	Influenced too much by extraneous factors
Hemoglobin	Muscle	Easy	Individual	No differentiation on fatigue
Red Blood-Cell Count	Muscle	Average	Individual	No differentiation on fatigue
Electrocardiograph	Muscle	Difficult	Individual	Little differentiation; very hard to give
Strength of Grip	Muscle	Easy	Individual	No differentiation
Lung Capacity	Muscle	Easy	Individual	No differentiation
Chest Expansion	Muscle	Easy	Individual	No differentiation
Steadiness (Needle Threading)	Nerve	Easy	Individual	No differentiation; inconstant
Two-Point Threshold (Esthesiometer)	Nerve	Easy	Individual	No differentiation

Verbal Reports on Riding-Fatigue

In our road-tests we have frequently found that the subjective manifestations of discomfort are greater than is indicated by the fatigue tests. This may be due to the fact that some elements of fatigue are unmeasurable by our present methods or that discomfort includes some elements entirely apart from fatigue itself. Whatever is the accounting factor, the verbal report of the subject or the rider is not to be neglected in judging his discomfort resulting from riding. In view of this we are attempting to standardize a score card for getting the verbal report of the individual's discomfort after riding. The score card is shown in Fig. 9.

At the end of a test trip a card is given to each individual to be filled in very shortly after the ride. A fatigue score for each individual is obtained by evaluating the four answers to the questions under *C* as 0, 1, 2, or 3 according to whether the answer is No or the successively higher degrees of discomfort. Absolutely no fatigue might then be said to be a 0 score and the most extreme fatigue a score of 34. On an all-day trip of moderately severe driving-conditions the median fatigue-score obtained was 19. All subjects tested showed a fatigue score over 10 for an all-day test-trip. We have also found, in studying this fatigue score-card, higher fatigue-records for those doing the driving on the trip than for most of those acting as passengers. Further standardization of the score card

and a correlation of the verbal report with the objective fatigue measures is contemplated.

Conclusions

Our conclusions to date may be summarized as follows:

(1) Muscular fatigue, produced by strenuous exercise over a short period, can be well measured by physiological tests of blood, metabolism and urine.

(2) Of the physiological tests applicable to the fatigue of automobile riding, basal metabolism and carbon-dioxide combining-power of the blood are most reliable.

(3) The fatigue from automobile riding is probably more nerve than muscle fatigue.

(4) Equilibrium, as measured by two differently recording wabblemeters, is markedly disturbed by long automobile riding. Other tests for nerve fatigue that have shown some differentiating value are number checking and mental multiplication.

(5) In fatigue produced over a long time, as by riding, fatigue counteractants, such as adrenalin, poured forth into the body seem to reduce the physiological manifestations.

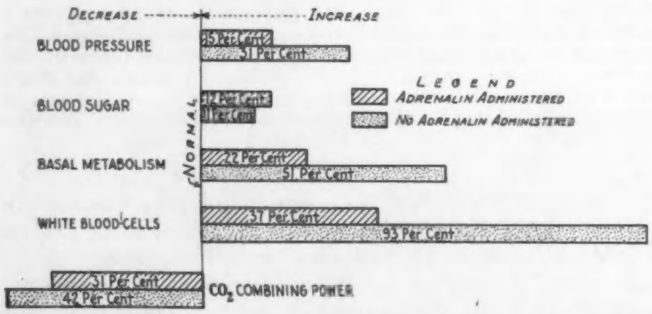


FIG. 8—RESULTS OF A STUDY MADE TO SHOW THE EFFECTS OF ADRENALIN UPON THE PHYSICAL MANIFESTATIONS OF FATIGUE

The Cross-Hatched Blocks Indicate the Results Obtained with the Administration of Adrenalin, While the Stippled Blocks Are Those in Which No Adrenalin Was Administered

(6) A score card of verbal reports of the riders gives additional information that is valuable in judging the fatigue from riding. Such a score card is being standardized for automobile test road-trips.

Plans for the Future

Our plans for future development and study include

(1) Further perfection and standardization of the two types of wabblemeter.

(2) Further standardization of the basal-metabolism test, including the establishment of normals for different times of day.

(3) The score card for verbal report of discomfort is to be studied further and improved.

(4) Other new measuring devices will be experimented with.

The standards for interpretation of wabblemeter results will involve the establishment of norms and corrections for age and sex of the individuals being tested, conditions of atmospheric temperature and pressure, time of day, equilibrium being better in the morning, and increase with practice. These standards for interpretation will make possible using the machines on road tests without an extra amount of preliminary experimenting with the subjects tested.

The machines having been perfected and standardized, using the same subjects over the same road, the differentiation in wabble between a ride of 100, 200, 300, 400 and 500 miles will be measured. Then we will determine whether the test method is suitable and applicable over the wide range of riding-comfort conditions through which it will be applied, over the same road and under the same conditions of driving, to a wide variety of cars, springs, shock-absorbers, cushions and so forth.

In our further experimentation we propose, first, investigation and application of tests to our own calibrated subjects in the laboratory; second, study of tests on a large number of taxicab and motorcoach drivers; and, third, application of the results with various outside groups of riders and test persons.

Verbal Report of Automobile Riders

A **Data on Trip**

Time started.......Time ended.......Miles traveled......

Number of stops made......Length of time of stops......

Kind of vehicle......Data......Weather conditions......

B **Personal Data**

Name........................Age..........Sex..........

Driver or rider..........Are you accustomed to riding daily in an automobile?..........If so, how much?............

Are you accustomed to taking long automobile trips?......

Did you feel normal at the beginning of this trip?........

C **Report of Discomfort at End of Trip—Underscore correct answers**

(1) Did you have any feeling of dizziness? None, slight, moderate, marked

(2) Did you have any headache? None, slight, moderate, marked

(3) Did you have any roaring in your ears? None, slight, moderate, marked

(4) Did your muscles feel stiff? No, slightly, moderately, very stiff

(5) Did your muscles feel sore? No, slightly, moderately, painfully

(6) Did your eyes feel tired? No, slightly, moderately, painfully

(7) Did you feel sleepy? No, slightly, moderately, very sleepy

(8) Did you have any nausea? None, slight, considerable, definitely upset

(9) When standing do you have a sensation as if you are falling forward? Yes, no

(10) Did you feel nervous? No, slightly, moderately, definitely shaky

(11) Basing your decision entirely on your present feelings would you prefer to stretch out on a cot or sit in a comfortable chair and read, play billiards or go to a good show, go to a dance or go swimming, go for another ride

(12) What sensations do you have that are not mentioned above? ....

....

FIG. 9—SCORE CARD USED TO SECURE A REPORT OF THE INDIVIDUAL'S DISCOMFORT AFTER BEING GIVEN A RIDING TEST

A Card Is Given to Each Individual at the End of a Test Trip for Indicating His Feelings. A Fatigue Score Is Obtained by Evaluating the Answers to the Degree of Discomfort Experienced, Absolute Absence of Fatigue Being Indicated by a Score of 0 and the Most Extreme Fatigue by 34

THE DISCUSSION

CHAIRMAN W. R. GRISWOLD[6]:—The subject of riding-qualities has interested engineers very much ever since the first automobile was designed. As engineers we have tried to develop instruments that would record or show the physical vibrations of the car and have spent considerable time on that. We have also put on springs, changed springs, put on shock-absorbers and taken them off and made various changes, and judged from our own personal impressions something about the riding-qualities. At best this was a rather unscientific way of trying to find out something of the measure of riding-qualities.

A number of years ago the Society sponsored a committee to investigate the correlation between the physical phenomena and the psychological reactions or physical reactions of the passenger. It has been a very interesting investigation and I am sure will result in the formulation of some definite laws connecting the physical characteristics of the automobile to the physiological reactions of the passenger and driver. The two differ and I would like to ask Dr. Moss what are the differences in the results to the driver after the test run of whatever mileage you had and the passenger.

Study of Physiological Effects Commended

DAVID BEECROFT[7]:—I think this work is amazingly important in view of the fact that last year we had a most alarming increase in the number of automobile accidents, an increase that is entirely out of proportion to the number of vehicles. It is a new condition that has arisen, because for three years previously we had no such increase. In talking with one of our Eastern motor-vehicle commissioners, he expressed the opinion that upward of 50 per cent of our accidents are due to lack of sufficiently quick physical reaction, and I feel that this work in studying the physiological effects of fatigue is one of the most constructive works that could be done at this time, in view of the fact that our motor-vehicle speeds have increased and also in view of the great increase in traffic.

W. G. WALL[8]:—I think this research work of Dr. Moss's is one of the most valuable pieces of work the Society has undertaken in a long while and we should also give much of the credit for this to Mr. Veal, who steered the committee in the right direction when this work was originally undertaken.

Will Dr. Moss state how he differentiates in these tests between the effect, on the subject, of the mechanical movement of a vehicle and that due to eye strain, watching the road, natural fear of accidents and things of that kind?

DR. F. A. MOSS:—In answer to Mr. Griswold's question about how the driver compares with the passenger, I can say that the former shows more fatigue than the latter in virtually all the tests. That is true particularly in the tests involving eye strain, such as number checking. He invariably falls down on those tests and also tends to show a slightly greater change in the reaction time.

We are trying to differentiate between the effect of the machine and eye strain in this way: We will put in the machine one of the recording accelerometers that are used now, and that will give us a very accurate report of just what the machine is doing. To a certain extent we can control the eye strain by using the same circuit of 2½ miles and going round and round it all the time.

W. R. STRICKLAND[9]:—How about making a comparison with a passenger who sits in a machine that is not moving for a time equivalent to riding 300 miles?

DR. MOSS:—We have not made those tests. To get people to sit in the machine for 6 or 8 hr. would be rather hard. The nearest approach to this was when we had the subjects sitting down doing mental multiplication, but there we had them at rather hard work from a nerve standpoint. I think that is a very good suggestion and should be followed.

Effects of Heavy Traffic and Poor Roads

L. K. SNELL[10]:—I suggest that a test be made of hours traveled through heavy traffic in comparison with the open road, as I think the results would be very interesting.

DR. MOSS:—We had one Sunday drive with a reckless driver through very heavy traffic, and it did give us a little more fatigue results that otherwise. These results did not show up in the blood, but tended to appear in the tests for nerve fatigue.

CHAIRMAN GRISWOLD:—In connection with this investigation I appreciate that the tests will have to be standardized to some extent if Dr. Moss is to continue his studies on riding-qualities.

I might mention a little experience I had this summer in driving to California and back with my wife and another couple. On two successive days we covered about the same distance. We had a Packard car, and the riding-qualities were fairly good, but on the first day to which I refer we were going through some wet gumbo in New Mexico. The car continually tried to skid from one side of the road to the other, and we had to slow our pace down to make the driving safe. That evening, when we got into Las Vegas, N. M., the ladies went to bed immediately. They did not even desire any food. The next day we went from Las Vegas to Albuquerque, over exactly the same types of road. As a matter of fact, we went through the mountain pass into Santa Fe, and on the whole the roads were somewhat more treacherous and would tend, I should think, to greater nerve fatigue than the roads on the previous day. However, the roads were dry, and that night when we got into Albuquerque, after faster driving and going over worse roads, I would say, from the standpoint of roughness, the ladies had no desire whatever to go to bed. They wanted to go to a show, which we all did. I think that this illustrates the effect of the element of fear in making tests of this sort and the necessity for standardizing them if that element is to be left out.

MR. BEECROFT:—What differences have you observed with different speeds of travel over these stated routes?

DR. MOSS:—We find that speed over bumpy roads, as such, does not seem to make so much difference. We took one of the worst roads we could find and drove around on it, backward and forward and made a kind

[6] M.S.A.E.—Engineer in charge of design analysis, Packard Motor Car Co., Detroit.

[7] M.S.A.E.—Vice-president, Bendix Corp., New York City.

[8] M.S.A.E.—Consulting engineer, Indianapolis.

[9] M.S.A.E.—Assistant chief engineer, Cadillac Motor Car Co., Detroit.

[10] M.S.A.E.—Eaton Axle & Spring Co., Detroit.

of circuit for about 7 hr. Although we were driving only about 20 or 25 m.p.h., we got very marked fatigue-results, whereas, when we drove at 35 m.p.h. on a good smooth road, we were not as much fatigued.

Factors To Consider in Future Tests

W. C. KEYS[11]:—Different weather and light conditions are factors that I think ought to be considered. My eyes are sensitive to light, and I find that it is very tiring to drive facing the sun.

Mr. Griswold touched on another point: confidence in the driver. One night recently I was in the mountains of Tennessee on icy roads that were extremely crooked. My partner was driving, and I almost went to sleep, having implicit confidence in that man's ability to pilot the car. Last summer I was riding in a car with a man who is somewhat of a naturalist. The driver was going rather fast over a rough road in the North Woods, and this passenger had his eyes glued to the road. As we passed over a stream that was very interesting to him, somebody called attention to it. He took one glance at the stream, and his eyes went back to the road, showing that he was really frightened over the ride.

Mr. Strickland touched on the difference between riding and sitting comfort in an automobile. Some cars give a good ride yet they are really uncomfortable as chairs to sit on.

Another factor is the difference between the ride in the front seat and the rear seat in the same automobile under the same conditions. We all know that the difference is tremendous. Ordinarily we find that a car traveling at moderate speed on a very rough road gives a much more comfortable ride in the front seat, but at the higher speeds and on fairly good roads, we get a better ride in the rear seat. Those differences should be studied and equalized as much as possible.

EDWARD P. WARNER[12]:—With remarkable consistency every bit of the discussion we have heard has been addressed essentially to the same fundamental subject, that necessarily an intermediate stage exists between the very remarkable pioneer work that Dr. Moss has done and the next step that he describes as about to be taken.

If Dr. Moss takes passengers out on the road in various automobiles and discovers that a 1930 Dodge rides better than a Model A Ford, or vice versa, that may be very valuable to the Dodge or Ford company, as the case may be, but it does not seem to me to be particularly valuable to those who are working on the fundamentals of riding-comfort. We already know that in many cases one car or one shock-absorber mechanism gives a better ride than another, on the average. What we want to know more about is, why; and I think this is the information Dr. Moss is putting us in the way of getting.

Study of Effects of Specific Motions

All of this discussion so far, with only minor exceptions, has concerned itself with some detail factor affecting comfort. I believe that the next, and the vital, thing to be done is to try to break this problem of comfort into its parts by reproducing various specific types of motion in the laboratory and observing their effect on the recorded comfort of the subjects as determined by these physiological means, or by testing, perhaps for brief periods, the subject in the car under conditions that are so closely controlled that only one or two of the factors expected to affect comfort can enter, instead of scores or hundreds of thousands that commonly make their appearance at some time in the course of a 500-mile ride.

The suggestion has been made that to sit in a motionless car may be more uncomfortable than to ride 500 miles in the same time. Dr. Moss spoke of controlling conditions by going round and round the track. I am sure that I would suffer very much more fatigue in 200 circuits of a total 500-mile course than in riding 500 miles from place to place.

We would like to know what the factors are, not merely about an instrument for determining that one shock-absorber is better than another or that somebody's car is good according to the accepted standards of average performance, but what controls comfort, what elements in motion are fundamentally comfortable and what are fundamentally objectionable. Then the problem becomes one for the engineer, not for the psychologist, to develop a mechanism that will eliminate the bad and accentuate the good.

One question is raised by Dr. Moss's paper which will make a marked change in the ground of my discussion. He passed over, I think without a full explanation, which perhaps would be difficult to give to non-medical men, the results of this adrenalin test to counteract fatigue factors. He remarked about the physiological tests showing so much less change after automobile riding, though the subjective and external signs of fatigue may be very great and this because of the longer period over which the development of fatigue is spread. Of course, as long as we are comparing only automobile rides, that might seem to be unimportant, but it raises the question of whether these measures depend on the way in which the fatigue develops. In other words, if we take a passenger out for two successive 200-mile rides, we produce actually the same amount of fatigue, subjectively measured, as though we took a passenger out for one 400-mile ride. In one case, however, the fatigue accumulates in the last 200 miles, and in that distance the difference in the result on the indications that have been developed will be marked, since the counteractive effect as produced in the body will have time to reduce the physiological measure of fatigue in the case where the disturbing elements appear very early in the ride and tests were not taken until after hours of subsequent very smooth riding.

Lines for Further Investigation

MR. STRICKLAND:—As I understand this matter, methods of measurement were the principal part of the investigation. I can see that we have gone a long distance ahead in this work. Following that, the shock-absorber and spring manufacturers and the chassis designers must proceed farther with this apparatus in the determination of the necessary changes to reduce the fatigue, so I think the discussion should be most helpful along the lines of assisting in the development of the methods, and that is what we are working on.

CHAIRMAN GRISWOLD:—Both Mr. Strickland and Mr. Warner have brought up some points in connection with the investigation which undoubtedly must be taken into account. As I understand it, this investigation was determined exactly along the lines that Mr. Strick-

[11] M.S.A.E.—Chief engineer, development department, United States Rubber Co., Detroit.

[12] M.S.A.E.—Editor, *Aviation*, New York City.

land has mentioned; that is, the idea was to determine what the physiological effects of riding-qualities are on the body of the passenger.

The discussion has brought out a number of other elements that may also affect the passenger, such as fear. I think that all of the discussion has been valuable in, perhaps, indicating to Dr. Moss how he should proceed in the future and how he must segregate some of the elements entering into the question that have no direct bearing at all on riding-comfort.

DR. MOSS:—The suggestion of controlling the variables and taking one at a time is a most excellent one, I think, and we expect to do that as nearly as possible by using the same subjects, taking them at the same time of the day, seeing that physiological conditions are as nearly as possible the same when we take them out in the morning, ride them in the same cars over the same track and, first, vary only the *time* they have been in the car or the number of miles they ride. Then we will take them the same way and vary only the *speed* at which they ride. Then we will change the car from time to time, and, to answer the very good suggestion that Mr. Warner made, we will try to get the fatigue that occurs early and is partly compensated by the release of adrenalin, just as we did in the blood-pressure test. In that test we took the blood pressure every minute during the time the man was riding the bicycle. Later on, we will do the same when riding in the automobile. If we are taking a group of men out for an 8-hr. ride, we will make a series of tests at the end of 1 hr., another at the end of 2 hr. and so forth; and we can control the conditions somewhat by making tests in between and plotting a curve accordingly.

R. W. BROWN[13]:—This discussion has been very interesting and has been pleasing to me, for I follow this work more or less personally. However, the discussion brings up the thought that we are prone to eat our cake before we bake it. At present, so to speak, Dr. Moss is stirring up the batter; obviously, we cannot eat the cake until we get the batter mixed, obtain an oven and bake it. The discussion does indicate a happy appetite for the riding-quality subject. The way to satisfy this appetite is for all who have a direct interest to contribute suggestions to Mr. Veal, the individuals on the Riding-Qualities Subcommittee or to Dr. Moss direct.

[13] M.S.A.E.—Chief of engineering laboratories, Firestone Tire & Rubber Co., Akron, Ohio.

The subject is extremely complicated and we cannot expect to get a single answer that will cover all the points that have been brought up in the discussion and probably innumerable others that are floating around in our minds at various times. I feel, personally, that the subject merits most hearty support.

Since our Subcommittee meeting in the City of Washington some months ago, I have had occasion to try out some of Dr. Moss's theories on subjects in industrial plants. The reaction in each case was distinctly favorable, but the results were not conclusive. The wabblemeter test could, for instance, be applied to persons who build tires on a piecework basis. Favorable results would be indicated by the same man working successive days on each of two types of tire-building machine that time-study shows to be even and finding that they differ by as much as 50 per cent. The productive result of the two machines has been the same in the past, but the physical effect has not been the same and the result is a distinct economic loss.

That is one of the indirect results, one of the by-products we might say, of this research work which may turn out, as some other by-products have, to be more valuable than the purpose of the initial research work. Again I ask all to give this matter consideration, because it is at the point now where we must either go ahead on a definite program or else stop, in which case the work done to date will be lost.

MR. STRICKLAND:—The tenor of the discussion has indicated that much more work remains to be done. I think Dr. Moss and the members of the Committee appreciate that fact very well, and no doubt the work will be continued.

A Diesel Engine in an Automobile

(*Concluded from p.* 512)

other the highest that can be expected. The entire trip, including returning to Columbus, Ind., was 2780 miles, and the entire fuel bill for the trip was $7.70; 0.28 cent per mile.

The flexibility of the Diesel engine and its ability to meet varying conditions of road and speed have been questioned. The real object of this trip was to test the engine in an automobile, because I know of no other application of an engine that presents so well every conceivable condition of load, speed and temperature. Weather conditions varied from about 73 deg. fahr., during record-breaking warm winter days in New York City, to 11 deg. below zero.

Performed as Well as a Gasoline Engine

In absolutely no way could a gasoline engine of equal size and speed limitation have performed better than did this engine. We knew that the engine was capable of hard pulling but have been much gratified to see how well it has met conditions of automobile service.

While in Pittsburgh, on the way home, I left the car in a parking lot to test cold-weather starting conditions. When I came back for the car, after three days, I was accosted by three men and was asked if I could start the car immediately. I did not know who the men were or how they knew me, but they told me that they were from a motorcoach company and had had the car watched day and night to see that nothing was done to it before it was started. The hood of the car had been left up, and snow enough had fallen to make it look as if the engine was buried in ice. I had never tried similar conditions before. However, I asked the men to get into the car, pushed out the clutch, engaged the reverse gear with the engine dead, started the engine on the first attempt, let in the clutch, backed out, and drove several blocks without faltering. Those were the conditions under which I demonstrated the ability of the engine to start in cold weather.

Transportation Engineering

Legal Restrictions on Vehicles

Motor-Vehicle Conference Committee's Recommendations Regarding Size, Weight and Speed

IN THE 1930 pamphlet on State Restrictions, the Motor-Vehicle Conference Committee, of New York City, states that, in behalf of the safety and convenience of vehicular and pedestrian movement on the highway and, second, to prevent uneconomic and unjustifiable wear and tear of highways, it has been found necessary to impose size, weight and speed limitations upon motor-vehicle use.

These restrictions have been imposed by State laws or by municipal ordinances in States in which the necessary power has been delegated to local governing bodies by the legislature or by liberal home-rule provisions in the State constitution. The Federal Government, while no doubt potentially able to impose size, weight and speed restrictions on motor-vehicles engaged in interstate commerce, has not yet taken steps in this direction. On the other hand, every tendency is away from municipal ordinances, especially in matters of size and weight restrictions, and in the direction of unqualified State control.

That the laws of the various States in the matter of operating limitations for motor-vehicles should be uniform is scarcely open to question. What the standards of such uniformity should be is therefore a vital consideration.

Compromise Is Necessary

Obviously, among the various kinds of highways and highway surfaces there are strips of mileage which will carry bigger, heavier and more swiftly moving vehicles than others. So, too, upon any one strip of some highways there are times of the year or conditions of weather when restrictions should be lower than are ordinarily deemed necessary. This at once raises the questions: (*a*) Shall the dimensions, weights and speeds of motor-vehicles and their loads be reduced to the capacities of the weakest highways or parts thereof; or (*b*) shall all highways and parts thereof be raised up to standards of improvement adequate to carry the biggest, heaviest and swiftest loads that users of motor-vehicles desire to place upon them?

The Motor Vehicle Conference Committee believes that between these two extremes lies a compromise which motor-vehicle manufacturers in designing their vehicles, highway engineers in building their roads and bridges, and public authorities in maintaining and regulating traffic upon them, would do well to follow.

Recommendations of the Committee

Translated into specific recommendations, the middle ground taken by the Conference Committee calls for the following:

SIZE RESTRICTIONS

On widths, including 96 in., and for traction engines, 108 in.; on height, including load, 14 ft. 6 in.; and on length, including load, 33 ft. for a single vehicle and 85 ft. for a combination of vehicles.

From the foregoing it is apparent that, to admit of the safe passage of two vehicles each of which with its load is 96 in. wide, a highway at least 20 ft. in width is desirable.

GROSS-WEIGHT RESTRICTIONS

(1) For a single vehicular unit of four wheels or less—a tractor, semi-trailer or trailer to be regarded as a separate unit—28,000 lb. A single vehicular unit of more than four wheels should be granted additional weight, irrespective of axle spacing.

(2) For one axle of a single vehicular unit of four wheels or less or any axle of a semi-trailer or trailer, 22,400 lb.

(3) The per inch width of tire to be measured between the flanges of the rim in the case of solid-rubber tires.

Size of Tire, In.	Minimum Load per Inch, Lb.
3	400
3½	400
4	500
5	600
6	700
7	750
8	800
10	800
12	800
14	800

(4) For solid-rubber tires,

Size of Tire, In.	Minimum Thickness of Rubber, In.
3, 3½, 4 and 5	⅞
6, 7 and 8	1
10, 12 and 14	1⅛

SPEED RESTRICTIONS

No motor-vehicle should be operated upon a public highway at a rate of speed greater or less than is reasonable and proper, having regard to the traffic and use of the highway, or so as to endanger the life or limb of any person or the safety of any property. Except in cases where municipalities may find it necessary to adopt different limits, the following speeds should be prima facie lawful, but in any case where such speeds would be unsafe, they should not be lawful:

Upon	M.P.H.
Urban streets	20
Suburban streets	25
Any other street or highway	40

The laws of many States prescribe for the three types of thoroughfare indicated a graduated schedule of speed limits based on the kind of tire equipment of the vehicle and its gross weight. Such elaborate and detailed schedules, however, are very difficult to enforce.

PERMITS TO RAISE RESTRICTIONS

At times it is imperative on certain highways or portions thereof that the movement of vehicles bigger and heavier than those allowed by law be permitted. To meet such situation, which should be the rare exception rather than the rule, the State, county or municipality exercising jurisdiction over roads and bridges should be empowered under definite limitations to grant written permits for the movement of restricted vehicles.

PERMITS TO LOWER RESTRICTIONS

To deal with bad frost or other similar conditions where it is essential to lower the weight or speed restrictions ordinarily enforced, the power of the State, as centralized in its highway departments or the county or local highway authorities, after consultation with and permission from the State Highway Department, should have power to reduce the weight or speed restrictions to points deemed essential to the preservation of highways or the safeguarding of travel. In all such cases, however, there should be public hearings on the subject; due notice of the reduced restrictions should be given to the traveling public, and the highways or portions thereof affected should be properly posted.

LOCAL POWERS

Except as indicated, the subordinate political subdivisions of the State, such as counties, cities, towns, boroughs and townships, should have absolutely no power to prescribe size, weight or speed restrictions at variance with those allowed for the State as a whole.

News of Section Meetings

(*Continued from p. 429*)

particular emphasis on the word "intelligent," endeavoring to give a boost to his own profession. His idea, however, that foreign cars are generally better looking than those produced here met with little encouragement. On that point, Mr. Chase later challenged the speaker, saying that American cars are equal to foreign makes artistically and otherwise. "But," said Mr. Chase, "I agree that artistic design is most important today."

Modern Car a Reaction Culmination

Oscar A. Eskuche was the second speaker. There is, he said, a definite relationship between design and service and the evolution of the modern vehicle is the culmination of one reacting on the other.

Adequate service is essential for automobiles because, no matter how well built a machine may be, there are always parts which wear out. As a matter of economics, the speaker continued, a small investment may often prove more advantageous than a large one. If efficient service is available, the owner is better off with moderately priced parts that wear out than with longer-wearing parts but no adequate service to replace them. Nor is it economical to build a car with certain parts of such sterling quality that they are in perfect condition when the car is junked. The One Horse Shay is ideal because no good parts are left over when the outfit is scrapped. The One Horse Shay idea is particularly desirable in heavy-duty vehicles so that a machine can be overhauled and made fit for another mileage period without throwing out half-worn parts or having to put back such parts and have the vehicle fail before the next overhaul.

In the design of a car there are construction details and relationships between parts which can be visualized sufficiently from the layout on the drawing-board to determine whether accessibility will admit of quick service, but here, said Mr. Eskuche, is where the average engineer weakens, as his attitude usually is, "We should worry about service; we want to make the design easy for the manufacturer and as cheap as possible."

Service Used To Be Easier

"Unfortunately," he continued, "not enough engineers actually service their creations. They should get under them themselves and not just listen to what a mechanic or experimental-department head reports. Reading a report is not as impressive as skinned knuckles."

The service man's job today, if anything, is harder than it was in the day of the "one-lunger," when 15 m.p.h. and 3000 miles per year were wonderful records. When it was necessary to get at the single spark-plug or adjust the two valves on the one-lunger, the body, which was hinged on one side, could be raised to give access to almost any part of the engine. Try to lean over the wide fenders of today, get around the spare wheels on the sides and under the hood, and adjust from 16 to 32 valves! When it was necessary to inspect the under part of the chassis in the old days, anyone could lie on a comfortable creeper and have room to work. Now, one cannot even get under with a newspaper between him and the floor.

Mr. Eskuche asked the engineering gathering some very pertinent questions. Are the wheels any easier to remove now? Are there fewer bolts in the rear axles? Has thought been given to draining the radiators, crankcases, transmissions or rear axles any quicker? Does not the quantity gage which is supposed to show the amount of oil in the engine still find a wonderful hiding place on most engines? Among other service factors he mentioned the following:

Accessibility Not Yet 100 Per Cent

Often a bolt is inserted in such a way that it takes two men to remove it, whereas if it were put in in the opposite way one man could do the job alone.

Carriage bolts still find their way into automobile specifications, as well as wood-screws with slots that seem to have been put there only as a means to remove the heads.

In removing a certain water-pump that is made as a unit assembly at the front of the block, the fan is in the way and the radiator has to be shoved forward. This cannot be done until the lamps are removed.

A magneto under and close to the exhaust pipe results in burned fingers when trying to reach the breaker box and in acquiring the art of working with a mirror.

To remove a timing-case cover, one engine must be moved back to relieve the front center-support, which cannot be done until the body is raised.

The battery in a car of the latest design is mounted on the engine.

Sometimes accessories on the dash must be removed before a certain cylinder-head can be raised.

A rear axle with torque-tube requires the removal of an axle to drop the transmission or to change clutch parts. Counterweights on the crankshaft or the crankcase cross-walls prevent the piston from being withdrawn from below, and the larger ends of the connecting-rods scratch the cylinders when pulled up through them.

A distributor located above the cylinder-head makes for accessibility, but it must come off with the head and may have to be retimed.

A cowl gasoline-tank avoids the use of a vacuum tank or fuel-pump but limits the passenger compartment.

The fork for the transmission reverse gear often gives trouble when trying to get it in place, as it extends to the bottom of the case. However, it is cheaper than a pivoted lever in the case, admitted the speaker.

Some Suggestions to Engineers

The engineer is "up against it," continued Mr. Eskuche, because the same vehicle is distributed all over the world. Certain minor changes must be made, and he looks to the service department to rectify the matter before the car is delivered or to attend to it after the trouble has come to the owner's attention. Varying topography or climatic conditions may require changes in rear-axle ratios, cooling system, carburetion, extra precaution against ingress of sand, or oil seals for highly crowned roads.

Modern design has made for better accessibility, better servicing and longer life of parts; for example, removable heads, alloy steels, heat-treatment, closer limits in manufacture, air-cleaners, oil-filters, crankcase ventilation, downdraft carburetion and oil-cooling. However, it has also made for headaches for the service man. Air-cleaners have upset carburetion by swirling the entering air and preventing normal jet action. Oil-filters are deceivers if the filter material is not replaced when it should be.

The beautiful apron below the radiator prevents the proper air-draft for cooling the crankcase in some cars.

Why should not the manufacturers' engineer design the tools necessary to service a car correctly and efficiently at the same time as the tools for manufacturing the car are designed? asked Mr. Eskuche, instead of letting the service man worry along and design ways and means himself, as he runs up against repairs on new models.

The engineers could save everybody considerable money if they would not try to nurse their babies quite so much and would take the service man more into their confidence and listen to his constructive criticism. Many improvements on cars are the result of the per-

sistence of the service man, who is on the firing line, in finally convincing the engineer "what's what."

Drilled holes in the bottom ring-grooves in pistons; connecting-rod spray holes for cylinder-wall lubrication; balancing ports between two manifolds on eight-cylinder carbureters by making a gap in gaskets between adjacent parts; simpler clutch designs; adequate oil-return passages in rear-axle differentials; air vents in transmissions and rear axles; bypassing oil from the pumps to prevent excessive pressures at high speeds, and hundreds of other suggestions and designs of tools to facilitate service should be credited to the service man.

"As you compare the one-lunger with the present-day car," Mr. Eskuche concluded, "it has been a case of redesign rather than design, as there are still plenty of the old ear-marks left. While today's car is a wonderful improvement over its predecessor in appearance, comfort, convenience, safety, performance and economy, the driver is still the same. The one big trouble before us all is that the engineer thus far has been unable to redesign the driver."

A Modern Metropolitan Service Station

Col. James W. Florida was the third speaker. He called to mind the old Vanderbilt race days when the Packard Long Island City plant was thought a monster building despite the fact that it was then only a third as big as it is now. When it was decided to move from Long Island City to Manhattan, there was some thought of establishing several stations but the idea was not carried out and results have justified the one-station policy. The new building, in which the meeting was held, and the land on which it stands cost approximately $2,000,000 and, with eight floors, basement and roof, provides more than 425,000 sq. ft. of floor space, said the speaker; yet, in less than a year, space is at a premium because accessibility of the station has brought it business that formerly went to competitors. New accounts were opened with more than 900 owners in the first 60 days.

Colonel Florida went on to describe the building in some detail, telling how the one-way double spiral ramps were an idea conceived from a staircase in an old castle in Rome. As compared with the side-by-side type, there is a saving of 1500 sq. ft. of space on every floor. To date, these ramps have carried cars on 40,000 trips without a scratch, a record which the speaker seemed to think warranted his having torn up 15 sets of blueprints before the final set was given his "check and double check."

That the testing track on the roof had a full complement of bumps, the Section members themselves could testify, having been driven over them previously. The parts department on the third floor, where more than 20 per cent of all Packard parts for the entire world are disposed of, received special notice, as did also the coach department which requires in itself some 45,000 sq. ft. of floor space.

A $20,000 dynamometer, a modern brake-testing machine and rollers for running-in and testing up to 45 m.p.h. were mentioned as particularly valuable pieces of equipment. Electrically controlled doorways are one of the many modern features.

Car handlings in this building are now at the rate of about 575 per week, or approximately 30,000 a year, said Colonel Florida, involving gross sales of $1,600,000 for 1929 and estimated sales of over $2,000,000 for the current year, with a profit every month so far. This is important, he pointed out, because it means efficient operation and the avoidance of waste.

Service Personnel Needs Personality

John F. Creamer, of Wheels, Inc., opened the discussion and was followed by David Beecroft, of the Bendix Aviation Corp., who as a car owner, remarked that the personality side of service-station work looms large in his view. This one item often determines the attitude of the public to service, and the public's attitude is a sure measure of service value. Automotive service must be maintained on a high level to meet the customers' service expectations which have been built up by hotels, department stores and others, to say nothing of the motor-car sales department itself.

In this connection Colonel Florida replied that a personnel with personality means everything and that it takes more than a good mechanic to make a service station today.

A. M. Welch, recently appointed New York branch manager of the Federal Motor Truck Co., said his first requirement was a real service manager who could go out and tame savage customers as well as run a repair depot. "I find," he remarked, "that you can separate them from more money in the end if you don't greet them with the old standby, 'Now what's the matter?'"

In answer to a remark about the customer being always right, Mr. Eskuche said that that is true up to a certain point. Give him the benefit of the doubt, is Mr. Eskuche's policy, but be firm when you are right and you will make a better customer in the end.

The flat-rate system was endorsed by Colonel Florida as eliminating many arguments and misunderstandings, which are a very real cause of customer difficulties. "Remember," he said in the midst of hearty laughter, "the customer doesn't come to the service station for a good time, anyway."

Austin M. Wolf, consulting engineer, spoke of design factors that help service. He mentioned grouped grease fittings, overhead valves and possible arrangements whereby a few tools can do the work of many. He pointed to the need for good material in die-castings, in timing gears and in cylinder-blocks. He also showed that the more highly developed a car is for specialized service, the more helpless is it when removed from a service-station locality. Body service was mentioned as a new and growing development.

Prof. E. F. Church and Capt. W. C. Thee, Q.M.C., also took part in the discussion. Others present included Professor Moore; Otis F. Presbrey, of the Otis Engine Corp.; S. G. Tilden, of S. G. Tilden, Inc.; H. H. White, of the White Motor Co., Captain Koch, of the New York Fire Department; William Low, of Smith & Gregory; and Roger Casler, of the Westinghouse Air Brake Co.

G. H.

Council Acts on Memberships and Sections

At a meeting of the Council held in New York on March 17 the following were present: President Warner, Past-President Strickland, Vice-Presidents Scaife and Horner, Councilors Glynn, Herrington and Moyer, and Treasurer Whittelsey.

The financial statement as of Feb. 28, 1930, was submitted. This showed a net balance of assets over liabilities of $245,401.65, this being $37,842.49 more than the corresponding figure on the same day of 1929. The gross income of the Society for the first five months of the fiscal year amounted to $176,091.78, the operating expenses being $160,454.99. The income for the month of February was $36,051.17, and the operating expense during the same month was $37,287.23.

Fifty-three applications for individual membership and 11 transfers in grade of membership were approved. Seven reinstatements were made and 9 applications reapproved. Ninety-six resignations were accepted and 18 members were dropped for non-payment of transfer fees accrued prior to Oct. 1, 1929.

The Council approved the organizing of probationary Sections at Syracuse and Baltimore, and also approved the change of name of the Pennsylvania Section to Philadelphia Section.

Personal Notes of the Members

Wood Promoted to Major

Edward C. Wood, superintendent of automotive equipment of the San Francisco division of the Pacific Gas & Electric Co., has been promoted to the rank of Major in the Quartermasters Reserve (Motors), United States Army. Mr. Wood has been active in the Society since he became a Member in 1924, having been charter member Chairman of the Northern California Section in 1926 and 1927 and a member of the Pacific Coast Committee of the Operation and Maintenance Committee from 1927 to the present time. He was a member of the Transportation Committee of the Society in 1929. A Personal Note about Mr. Wood appeared in the S.A.E. JOURNAL of August, 1928, p. 219.

Captain Land Returns to Navy

Subsequent to having served as vice-president and treasurer of the Daniel Guggenheim Fund for the Promotion of Aeronautics in New York City, Capt. Emory Scott Land (C.C.), U.S.N., has returned to his naval duties and is now a member of the staff of the Commander-in-Chief of the United States Fleet. His work on the staff is that of fleet naval constructor, and his headquarters are on the U.S.S. Texas.

Born at Cañon City, Colo., in 1879, Captain Land studied at the University of Wyoming, receiving the degrees of Bachelor of Arts and Master of Arts; at the United States Naval Academy; and at Massachusetts Institute of Technology, from which he received his Master of Science degree in 1907. Since 1898 he has been attached to the United States Navy and rendered greatly diversified service, as indicated in the following outline:

Attached to China station under Admiral R. D. Evans, 1902 to 1904; post-graduate course in naval architecture at the Massachusetts Institute of Technology, 1904 to 1907; work at the Brooklyn Navy Yard in the Material Division, and on new construction including the ships Vestal, Florida and New York, 1907 to 1911; at Navy Department Bureau of Construction and Repairs, 1911 to 1914; as Naval Fleet Constructor, 1914 to 1916; on submarine design in the City of Washington, 1916 to 1918; attached to the staff of Admiral Sims, 1918 to 1919; work on submarine design in the Bureau of Construction and Repair and cooperating with the British on airship contracts, 1919; assistant naval attaché and acting aviation attaché of the American Embassy in London, 1919 to 1921; at Bureau of Aeronautics of the Navy Department, as head of the Material Division from 1921 to 1926, and as assistant chief of the Bureau until 1928; finally, on leave of absence for one year in the Guggenheim organization.

In October, 1928, Captain Land became a Service Member of the Society and last year served as Chairman of the Aircraft Committee. At the Cleveland Aeronautic Meeting in 1929 he acted as Toastmaster at the Aeronautic Dinner.

Advancement of K. T. Brown

Knox T. Brown has been appointed general manager of the Packard Motor Car Co. of Boston, with which he has been connected since 1920.

After being graduated from high school, Mr. Brown engaged in the automobile sales and service field from 1906 to 1918, operating his own business. He then joined the United States military forces, serving as motor inspector in the Army Air Service until 1920.

Upon being mustered out, Mr. Brown accepted the post of general service manager with the Boston Packard organization. During the following ten years his responsibilities increased and came to include shop production and service, coach and paint-shop management, Packard field-service representation at Detroit, and technical supervision of four Packard branches and 64 dealers in New England.

Entering the Society in February, 1925, as Associate Member, Mr. Brown was transferred to Member grade in November, 1928. Since 1925 he has been a member of the New England Section, and during 1929 served as its Chairman. He presented a paper entitled, Present-Day Automobile Service, at the December, 1922, meeting of the Section.

Gregg with Eclipse Aviation

Having severed his connection with the Delco-Remy Corp., of Anderson, Ind., David Gregg has accepted an engineering post in the organization of the Eclipse Aviation Corp., of East Orange, N. J.

Since his graduation from a course in military aeronautics at Queens College, Oxford, England, in 1917, Mr. Gregg has been engaged in the aviation field. Until December, 1918, he was attached to the Royal Flying Corps from the United States Air Service, acting as instructor, test pilot and ferry pilot; in fact, he had been interested in flying since 1912, when he first ascended in a Wright airplane. He received his Bachelor of Arts Degree from Harvard University in 1918, and attended Harvard Engineering School from 1918 to 1920. The following year he entered the cost department of the Boston Belting Co., of Boston, and in 1922 became aeronautical mechanical engineer in the powerplant section of the United States Air Service at McCook Field, Dayton, Ohio. There, from 1924 to 1927, he did research and consulting work on superchargers. Three years ago he became engineer with the A C Spark Plug Co., of Flint, Mich., where he remained until, in 1929, he entered the Delco-Remy organization.

Mr. Gregg's membership in the Society dates from April, 1920, when he became a Member. He was transferred to Service Member grade in August, 1921, when he took up the work at McCook Field, and was restored to Member grade after his resignation from the Government Service.

Begg with Midland Steel Products

E. J. Kulas, president of the Midland Steel Products Co., of Cleveland, has announced that Russell S. Begg, until recently chief engineer of the Stutz Motor Car Co., of Indianapolis, has been appointed chief engineer of the Midland concern. He will direct the company's engineering activities, including its new experimental laboratory.

After concluding his engineering studies at Northwestern and Michigan Universities, Mr. Begg became connected as draftsman with the Packard Motor Car Co., of Detroit, and remained there from 1907 to 1909. Subsequently he rendered similar service and did road-test and repair work for the Chalmers Motor Car Co. and the Hudson Motor Car Co., of Detroit. In 1911 he took charge of the specification department of the E. R. Thomas Motor Car Co., of Buffalo, and the year following became superintendent of the truck department of the Sheldon Axle Co., of Wilkes-Barre, Pa. Late in 1912 he was engaged by the Thomas B. Jeffery Co., of Kenosha, Wis., to direct experimental work at its plant. In 1918 he became chief engineer for the Jordan Motor Car Co., of Cleveland. Eleven years later he assumed such a position with the Budd Wheel Co. and also became associate engineer for the Edward G. Budd Mfg. Co., of Detroit.

Ever since becoming a Member in 1914, Mr. Begg has been active in So-

(*Continued on p.* 44)

Applicants Qualified

The following applicants have qualified for admission to the Society between Feb. 10 and March 10, 1930. The various grades of membership are indicated by (M) Member; (A) Associate Member; (J) Junior; (Aff.) Affiliate; (S M) Service Member; (F M) Foreign Member.

ABERCROMBIE, RALPH PIDGIN (A) salesman, Bausch Machine Tool Co., Springfield, Mass.; (mail) 1834 Dime Bank Building, *Detroit*.

ANDERSON, HAROLD EDWARD (J) commercial car engineering department, Studebaker Corp. of America, *South Bend, Ind.*; (mail) 1015 West Colfax.

ANDERSON, O. M. (A) secretary, treasurer, Northern Automotive Supply Co., 911 North Water Street, *Bay City, Mich.*

AUSTIN, LOUIS J. (J) vice-assistant body engineer, engineering department, General Motors of Canada, Ltd., *Oshawa, Ont., Canada*.

BAKER, GORDON C. (J) weight-control engineer, engine department, Curtiss Aeroplane & Motor Co., *Garden City, N. Y.*

BARRY, A. M. (A) president, general manager, St. Lawrence Welding & Engineering Works, Ltd., 2101 Aird Avenue, Maisonneuve, *Montreal, Que., Canada*.

BARRY, HENRY B., MAJOR (A) U. S. A., Quartermaster Corps, Room 2202, Munitions Building, *City of Washington*.

BAUER, WALTER C. (M) test engineer, automotive research, Standard Oil Development Co., Bayway, Elizabeth, N. J.; (mail) 43 Gesner Street, *Linden, N. J.*

BOCK, CARL F. (A) parts manager, Twin City Chevrolet Co., *Lewiston, Idaho*; (mail) 227 Second Avenue.

BOWERS, RAYMON (M) automotive engineering, International Harvester Co. Experimental Laboratory, *Chicago*; (mail) 824 East 53rd Street, 3D.

BOWLER, H. A. (A) president, manager, City Tire Shop, 929 West Second Avenue, *Spokane, Wash.*

BOYS, HENRY CECIL, CAPT. (F M) assistant superintendent of design, Royal Arsenal Design Department, Room 46, Central Office, *Woolwich, S. E.* 18, *England*.

BURKHOLDER, FRED O. (A) vice-president, sales manager, Ahlberg Bearing Co., 321 East 29th Street, *Chicago*.

CASH, V. T. (J) draftsman, Wichita Falls Motor Co., *Wichita Falls, Texas*; (mail) 1009 Eighth Street.

CULTER, RALPH E. (A) salesman, Ferodo & Asbestos, Inc., New Brunswick, N. J.; (mail) 347 Ainsworth Avenue, *Portland, Ore.*

DENES, HUGO (M) engineer, Denes & Friedmann, A. G., Mitterberggasse 11, *Vienna* 18, *Austria*.

DICK, CHARLES L. (A) partner, service and sales manager, Bennett's Garage, Fourth and D Streets, *Lewiston, Idaho*; (mail) Box 190.

DROHMAN, LAURENCE H. (J) time study, National Twist Drill & Tool Co., *Detroit*; (mail) 20251 Hull Street.

ENKE, PAUL A. (J) sales correspondent, Johns-Manville Corp., *Chicago*; (mail) 6915 Michigan Avenue.

GAGE, WILLIAM M. (A) assistant sales manager, Buick Motor Co., Detroit; (mail) 2061 Avon Lane, *Birmingham, Mich.*

GANZENHUBER, PAUL (A) body draftsman, Fisher Body Corp., *Detroit*; (mail) 5529 Nottingham.

GRESHAM, A. E. (M) chief engineer, aircraft department, Standard Steel Works, North Kansas City, Mo.; (mail) 3817 Paseo Boulevard, *Kansas City, Mo.*

HALL, KENNETH D. (J) aircraft engineer, Swallow Airplane Co., *Wichita, Kan.*; (mail) 939 Porter Avenue.

HAMMOND, CHARLES F., JR. (A) sales engineering, Gemmer Mfg. Co., Detroit; (mail) 680 Rivard Boulevard, *Grosse Pointe, Mich.*

HARLOW, MAX B. (M) chief engineer, Bach Aircraft Co., Inc., Los Angeles Metropolitan Airport, *Van Nuys, Calif.*

HAZEN, FREDERICK W. (M) vice-president, in charge of production, Whittelsey Mfg. Co., Bridgeport, Conn.; (mail) 2201 Amsterdam Avenue, *New York City*.

HICKS, HAROLD A. (M) aircraft engineer, Stout Metal Airplane Co., Division of Ford Motor Co., Dearborn, Mich.; (mail) 14377 Abington Road, *Detroit*.

HOLMSTROM, JOHN G. (J) chief engineer, Kenworth Motor Truck Corp., 1263 Mercer Street, *Seattle, Wash.*

JOHNSON, CARL V. (M) aeronautical engineed, development work, Bendix Brake Co., *South Bend, Ind.*; (mail) 1237 East Bronson Avenue.

JOHNSON, HORACE L. (A) engineering, F. N. Ross, Consulting Engineer, 1010 Beaubien Street, *Detroit*; (mail) 9317 Pinehurst Street.

KELLER, ANSON MORE (M) engineer, Ryan Aircraft Corp., Robertson, Mo.; (mail) 103 Lawrence Avenue, *Ferguson, Mo.*

KENT, W. A. (A) supervisor of delivery, T. Eaton Co., Ltd., *Toronto, Ont., Canada*; (mail) 254 Wright Avenue.

KILLMEYER, CHESTER A. (A) carbureter specification engineer, Tillotson Mfg. Co., *Toledo, Ohio*.

KURTH, LUROFF D. (A) machinist, Colyear Motor Sales, *Spokane, Wash.*; (mail) 1627 West Dean.

LEMAIRE, M., PROF. (F M) Ecole Centrale Lyonnaise, *Lyons, France*.

LIDDELL, GEORGE J. (J) experimental engineer, Houde Engineering Corp., 537 East Delavan Avenue, *Buffalo*.

LONG, J. F. (M) general manager, chief engineer, J. F. Long, Inc., 2432 Ashby Avenue, *Berkeley, Calif.*

MATSON, RANDOLPH (J) chief engineer, Southwest Aviation Co., *Glendale, Calif.*; (mail) 133 North Jackson Street.

MAYNARD, ALBERT A. (M) truck engineer, Adam Opel A. G., Russelsheim, Germany; (mail) 10-123 General Motors Building, *Detroit*.

McFARLANE, COLIN J. (A) representative, Ethyl Gasoline Corp., New York City; (mail) 1509-26th Avenue, S. W., *Calgary, Alberta, Canada*.

McGOUGHRAN, C. F. (A) assistant district manager, Sinclair Refining Co., 173 Walton Street, N. W., *Atlanta, Ga.*

MELBY, EINAR C. (M) sales representative, DeSoto Motor Corp., Division of Chrysler Corp., Detroit; (mail) Eastland Hotel, *Portland, Maine*.

MILLER, JOSEPH PAUL (J) design draftsman, Horace E. Dodge Boat Works, *Detroit*; (mail) 151 Seward Avenue.

MOORE, HOWARD JAMES (A) manager, parts and service division, Durant Motors of Canada, Ltd., Box 220, *Leaside, Ont., Canada*.

MORGAN, THOMAS JAY (A) Hartford Empire Co., *Hartford, Conn.*; (mail) 116 Sisson Avenue.

MOYSE, D. W. (A) district garage foreman, Shell Oil Co., Seattle, Wash.; (mail) Automotive Department, Shell Oil Co., *Spokane, Wash.*

MUELLER, CARL ERNST (J) designer, tools, dies, special machinery, A. O. Smith Corp., *Milwaukee*; (mail) 394 South Summit Avenue.

NELSON, CHARLES E. (A) service superintendent, Harrington Motor Co., *Minneapolis*; (mail) 5228 Knox Avenue, South.

NELSON, RICHARD HERMAN (J) production manager, Herman Nelson Corp., *Moline, Ill.*; (mail) 2910-16th Avenue.

NEWCOMB, LEROY (J) engineer, Transportation Management Corp., New York City; (mail) care Yellow Cab Co., Ross Street Garage, *Pittsburgh*.

NUSBAUM, EMIL J. (M) standardization engineer, Briggs Mfg. Co., *Detroit*; (mail) 12126 Greenlawn.

ORR, LEIGHTON (J) technical data department, Cadillac Motor Car Co., Detroit; (mail) 2929 Belrose Avenue, *Dormont, Pittsburgh*.

PATTERSON, ALLEN B. (A) automotive engineer, The Texas Co., *Chicago*; (mail) 4802 Kenmore Avenue.

PENNINGTON, JOHN HAWLEY (F M) lubrication engineer, Vacuum Oil Co., Proprietary, Ltd., Box 512, *Dunedin, New Zealand*.

QUEST, WILLIAM (J) experimental engineer, Le Roi Co., *West Allis, Wis.*

REYNDERS, JOHN F. (J) draftsman, Rolls-Royce of America, Inc., East Springfield, Mass.; (mail) 200 Buckingham Street, *Springfield, Mass.*

SHARP, GEORGE EDWARD (F M) chief draftsman, Dunlop Rim & Wheel Co., Ltd., *Foleshill, Coventry, England*.

SHRIER, EMERSON NELSON (A) instructor in automobile mechanics, Windsor Walkerville Technical School, Giles Boulevard, *Windsor, Ont., Canada*.

STEINDLER, JULIUS (F M) managing director, Denes & Friedmann A. G., Mitterberggasse 11, *Vienna, Austria*.

STEPHEN, GEORGE MATHIESON (A) teacher of automobile mechanics, Board of Education, *Toronto, Ont., Canada*; (mail) 100 Greenwood Avenue.

TERRETT, REGINALD ST. JOHN (J) assistant body engineer, General Motors Corp. of Canada, Ltd., *Oshawa, Ont., Canada*; (mail) 630 Mary Street.

TIMM, FRITHIOF V. (A) transportation engineer, General Motors International, A/S, *Copenhagen, Denmark*.

TURNER, GILBERT H. (J) assistant to vice-president, Timken Roller Bearing Co., *Canton, Ohio*; (mail) Y. M. C. A.

VOIGT, ALBERT G. (A) mechanical engineer draftsman, American Car & Foundry Co., New York City; (mail) 16 Prospect Terrace, *East Rutherford, N. J.*

WALKER, SYDNEY (F M) works manager, Laycock Engineering Co., Ltd., Millhouses, *Sheffield, England*; (mail) 51 Dobcroft Avenue.

WEBER, C. W. (M) automotive engineer, The Texas Co., New York City; (mail) 456 Merion Road, *Merion, Pa.*

WHITE, HOLLIS A. (A) experimental engineer, James Cunningham, Son & Co., *Rochester, N. Y.*; (mail) 227 East Henrietta Road.

WHITEHEAD, ENNIS CLEMENT (S M) First Lieutenant, Army Air Corps, Wright Field, *Dayton, Ohio*.

WOODWARD, CHARLES ROBERT, JR. (J) draftsman, mechanical automotive layout and design, American LaFrance & Foamite Corp., *Elmira, N. Y.*; (mail) 424 West Gray Street.

WOODWORTH, O. B. (A) assistant service manager, Buda Co., *Harvey, Ill.*; (mail) 148 East 153rd Street.

WRIGHT, RICHARD N. (A) service manager, Hubert J. Wright, Inc., 524 East Genesee Street, *Syracuse*.

ZIRCKEL, HAROLD W. (A) district mechanic, Associated Oil Co., *Seattle, Wash.*; (mail) 4534 11th Avenue, Northeast.

Applicants for Membership

The applications for membership received between Feb. 15 and March 15, 1930, are listed below. The members of the Society are urged to send any pertinent information with regard to those listed which the Council should have for consideration prior to their election. It is requested that such communications from members be sent promptly.

ALLEE, HERBERT D., production manager, Studebaker Corp. of Canada, Ltd., *Walkerville, Ont., Canada.*

ALLEN, WILLIAM C., consulting engineer, Alco Oil Tool Co., *Compton, Calif.*

BAEYERTZ, FRANK, manager lubricating oil sales, Standard Oil Co. of New Jersey, *Newark, N. J.*

BARNKOW, CARL O., mechanical engineer, General Development Co. of Connecticut, *New York City.*

BENZ, AUGUST, president, Benz Spring Co., Inc., *Portland, Ore.*

BOYER, GLENN C., assistant engineer, Burns & McDonnell Engineering Co., *Kansas City, Mo.*

BURGESS, ROBERT W., resident engineer, Q. C. Engineering & Tool Sales, Inc., *New York City.*

CARRY, JAMES B., superintendent of garage, automotive transportation, Chestnut Farms Dairy, Inc., *City of Washington.*

CASSIDY, JAMES F., librarian, Standard Oil Co. of California, *Richmond, Calif.*

CHISOLM, ALFRED DE J., branch automotive superintendent, South Carolina, Standard Oil Co. of New Jersey, *Columbia, S. C.*

CICALA, JOHN, student instructor, Cass Technical High School, *Detroit.*

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COCHRANE, T. HARRY, metallurgist, T. H. Cochrane Laboratories, *Milwaukee.*

COLE, CLIFFORD, mechanic, Cole Sales & Service, *De Witt, Mich.*

COLLINS, JOHN L., sales engineer, New Process Gear Co., *Syracuse, N. Y.*

COLVIN, HENRY F., vice-president, Pioneer Instrument Co., *Brooklyn, N. Y.*

DELAHUNTY, FRANK H., secretary and treasurer, O. & S. Bearing Co., *Detroit.*

DE LARREA, MANUEL LEON, mechanical draftsman in charge of designing, Central Power & Light Co., *San Antonio, Texas.*

DEVITT, NORMAN WRIGHT, managing director, Hall Gear & Machine Co., Ltd., *Toronto, Ont., Canada.*

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DUNCAN, DON M., assistant to chief engineer, Duplex Printing Press Co., *Battle Creek, Mich.*

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FADENBAUER, CHARLES CHRISTIAN, shop superintendent, John A. McCarthy & Co., Inc., The Bronx, *New York City.*

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FORD, GEORGE E., machine designer, Gleason Works, *Rochester, N. Y.*

GARY, CURTIS LOUIS, body draftsman and designer, Briggs Mfg. Co., *Detroit.*

GLAZEBROOK, JAMES ROBINSON, assistant physicist, Johns-Manville Corp., *Manville, N. J.*

GLEESON, W. B., sales engineer, O. & S. Bearing Co., *Detroit.*

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HUNTER, ROBERT H., vice-president and superintendent, Johnson Bus Lines, Inc., *Milford, Mass.*

JACOBSON, HENRY A., designing engineer, The Norton Co., *Worcester, Mass.*

JUND, DANIEL, factory contact engineer, Apollo Magneto Co., *Kingston, N. Y.*

KEITH, WILLIAM D., president, William D. Keith-Marmon, Inc., *Shreveport, La.*

KENNEDY, LOGAN HAMILTON, service manager, Whittelsey Mfg. Co., *Bridgeport, Conn.*

KIDD, ROY WILFRID, in charge of repair and overhaul shop, Western Air Express, *Los Angeles.*

KOCH, J. M., general sales manager, Quaker State Oil Refining Co., *Oil City, Pa.*

KOMAMURA, TOSHIZO, captain, Japanese Army, Rikugun, Kokuhonbu, Gijitsubu, Tachikawa, *Tokyo-Fu, Japan.*

KORIAGIN, VSEVULOD BASIL, chief engineer, Lincoln Aircraft Co., Inc., *Lincoln, Neb.*

LEBLOND, RICHARD E., president, LeBlond Aircraft Engine Corp., *Cincinnati.*

LEMAIRE, PIERRE, professor, Institut Technique de la Faculte des Sciences de University de Lyon, *Lyon, France.*

LOMBARD, ALBERT E., structural engineer, Curtiss Aeroplane & Motor Co., Inc., *Garden City, N. Y.*

MACLEAN, ANDREW DYAS, editor, Canadian Power Publications, *Toronto, Ont., Canada.*

MARKLAND, STANLEY, engineer in charge of research department, Leyland Motors, Ltd., *Leyland, Lancashire, England.*

MARTINUZZI, PIO FRANCO, head of experimental drawing office, Sunbeam Motor Car Co., *Wolverhampton, England.*

MATHES, DUDLEY C., general foreman, repair shop, grade 4, California Highway Commission, *Redding, Calif.*

MCDOWELL, EDWARD P., superintendent of transportation, Hecker, Jones, Jewell Milling Co., *New York City.*

MCAFEE, D. D., garage foreman, Safety Transit Co., *Raleigh, N. C.*

MEUWLY, FELIX HARRY, student, Little Rock College, *Little Rock, Ark.*

MIKAN, IVAN, JR., repairing Stromberg carbureters, Joseph Woodwell Co., *Trafford, Pa.*

NELSON, GEORGE J., factory manager, Overman Cushion Tire Co., Inc., *Belleville, N. J.*

NESBITT, J. W., factory manager, Chrysler Corp., Highland Park plant, *Detroit.*

O'LEARY, ALWYNN ST. CLAIR, proprietor, Central Motors, *Abbottabad, N. W. F. P., India.*

OSBORN, BALDWIN, service engineer, Wright Aeronautical Corp., *Paterson, N. J.*

PAUL, DAVID SPEIRS, manager, technical sales department, Anglo-American Oil Co., *London, England.*

PEDERSEN, BRANDT, checker, engine and chassis design, H. H. Franklin Mfg. Co., *Syracuse, N. Y.*

PEO, RALPH FREDERICK, vice-president and general manager, Houde Engineering Corp., *Buffalo.*

POLLARD, HAROLD, branch manager, Leyland Motors, Ltd., *Montreal, Que., Canada.*

POTGIETER, FRED M., vice-president, engineer, Universal Gear Corp., *Chicago.*

RUMMLER, FRANCIS J., chief engineer, dynamometer division, Metal Stamping Co., *Long Island City, N. Y.*

SCOTT, WILLIAM F., bus engineer, International Motor Co., *Allentown, Pa.*

SHAVER, W. A., sales engineer, Warner Electric Brake Corp., *Beloit, Wis.*

SHELTON, WILLIAM J., experimental department, Timken-Detroit Axle Co., *Detroit.*

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THYSSE, JOHN, assistant engineer, Hercules Motors Corp., *Canton, Ohio.*

VANCURA, EMIL, president, Vancura Machine Co., *Long Island City, N. Y.*

VON MERTENS, ERNST, draftsman, Robert Bosch Magneto Co., Inc., *Long Island City, N. Y.*

WELLS, CHESTER R., engineer in charge of brake development, Stewart-Warner Corp., *Chicago.*

WHEELER, GEORGE F., chief of industrial investigations division, Black & Bigelow, Inc., *New York City.*

WILKINSON, GEORGE SHAKESPEARE, chief engineer, D. Napier & Son, Ltd., *Acton, London, England.*

WILLIAMS, GEORGE L., student, Massachusetts Institute of Technology, *Cambridge, Mass.*

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YASHIRO, FUSAO, commercial engineer, Shiba, Kanasugi, Shibauro Engineering Works, *Tokyo, Japan.*

Notes and Reviews

AIRCRAFT

Test of an Adjustable-Pitch Model Propeller at Four Blade Settings. By E. P. Lesley. Technical Note No. 333. Published by the National Advisory Committee for Aeronautics, City of Washington, 1930; 15 pp., 11 figures. [A-1]

The tests reported show that propellers of the type studied may be considerably changed in setting from the designed pitch angles and yet give excellent performance.

Comparative Performance Obtained with XF7C-1 Airplane Using Several Different Engine Cowlings. By Oscar W. Schey, Ernest Johnson and Melvin N. Gough. Technical Note No. 334. Published by the National Advisory Committee for Aeronautics, City of Washington, 1930; 17 pp., 14 figures. [A-1]

Although the research that has been conducted on the cowling of radial air-cooled engines has resulted in the improvement of the performance of airplanes equipped with this type of engine, it has introduced other problems, such as visibility, accessibility, cooling and the necessary modifications of airplanes now in service. The tests reported in this Note were conducted for the purpose of investigating further these problems attendant to cowling.

Full-Scale Wind-Tunnel Tests on Several Metal Propellers Having Different Blade Forms. By Fred E. Weick. Report No. 340. Published by the National Advisory Committee for Aeronautics, City of Washington, 1930; 13 pp. illustrated. [A-1]

This report gives the full-scale aerodynamic characteristics of five different aluminum-alloy propellers having four different blade forms. They were tested on an open-cockpit fuselage with a radial air-cooled engine having conventional cowling, in the N.A.C.A. 20-ft. propeller research tunnel.

The results show that (*a*) the differences in propulsive efficiency due to the differences in blade form were small; (*b*) the form with the thinnest airfoil sections had the highest efficiency; (*c*) it is advantageous as regards propulsive efficiency for a propeller operating in front of a body, such as a radial engine, to have its pitch reduced toward the hub.

The External Forces on an Airship Structure with Special Reference to the Requirements of Rigid-Airship Design. By Harold Roxbee Cox. Published in *The Journal of the Royal Aeronautical Society*, September, 1929, p. 725. [A-1]

These items, which are prepared by the Research Department, give brief descriptions of technical books and articles on automotive subjects. As a general rule, no attempt is made to give an exhaustive review, the purpose being to indicate what of special interest to the automotive industry has been published.

The letters and numbers in brackets following the titles classify the articles into the following divisions and subdivisions: *Divisions*—A, Aircraft; B, Body; C, Chassis Parts; D, Education; E, Engines; F, Highways; G, Material; H, Miscellaneous; I, Motorboat; J, Motorcoach; K, Motor-Truck; L, Passenger Car; M, Tractor. *Subdivisions*—1, Design and Research; 2, Maintenance and Service; 3, Miscellaneous; 4, Operation; 5, Production; 6, Sales.

This is a very comprehensive and technical article occupying eighty-six pages in *The Journal of the Royal Aeronautical Society* and treating all the possible combinations of the components in airship design.

The author analyzes the external forces on the structure of a rigid airship into component systems due to (*a*) weights of the members of the structure and the weights of the masses carried by it; (*b*) lift and pressure of the gas; (*c*) aerodynamic forces consequent upon the relative motion of the airship and the air; (*d*) thrusts of the airscrews; (*e*) and reactions due to the mooring arrangements, the hauling-in guys, the supports used in the shed, or handling on the ground. He points out that, since these component systems, though restricted by their interdependence, are individually variable, a very large number of complete systems is represented by the possible combinations and variations that can occur. These possible combinations are considered in the article under a wide range of conditions.

French Wind-Tunnel Methods. By M. Lapresle. Published in *The Journal of the Royal Aeronautical Society*, October, 1929, p. 838. [A-1]

M. Lapresle is director of the Eiffel Laboratory and in this article briefly reviews the rôle of aeronautic laboratories in France. The methods used in present practice in making wind-tunnel tests are described in considerable detail and accompanied by numerous photographs and diagrams.

This issue of *The Journal of the Royal Aeronautical Society* is, in a sense, an international number, since it contains the following contributions covering research work in other European countries:

Aeronautical Research in Sweden, by K. Angstrom, secretary to the Swedish Aeronautical Committee; Recent Progress of Aeronautical Science in France, by P. Franck; Aeronautical Progress in Great Britain, by H. E. Wimperis, director of scientific research at the Air Ministry; An Historical Survey of Italian Aeronautics, by R. Giacomelli; and the Development of Aviation and Aeronautical Research in Holland in Recent Years, by H. J. Van Der Maas.

The Interference Between the Body and Wings of Aircraft. By J. H. Parkin and G. J. Klein. Published in *The Journal of the Royal Aeronautical Society*, January, 1930, p. 1. [A-1]

Tests on certain aircraft having disclosed discrepancies between the characteristics estimated from the figures for the individual components and those observed for the complete model, the investigation herein reported was undertaken to determine the nature and magnitude of the effects of interference between the body and wings of aircraft and to ascertain the factors influencing the interference.

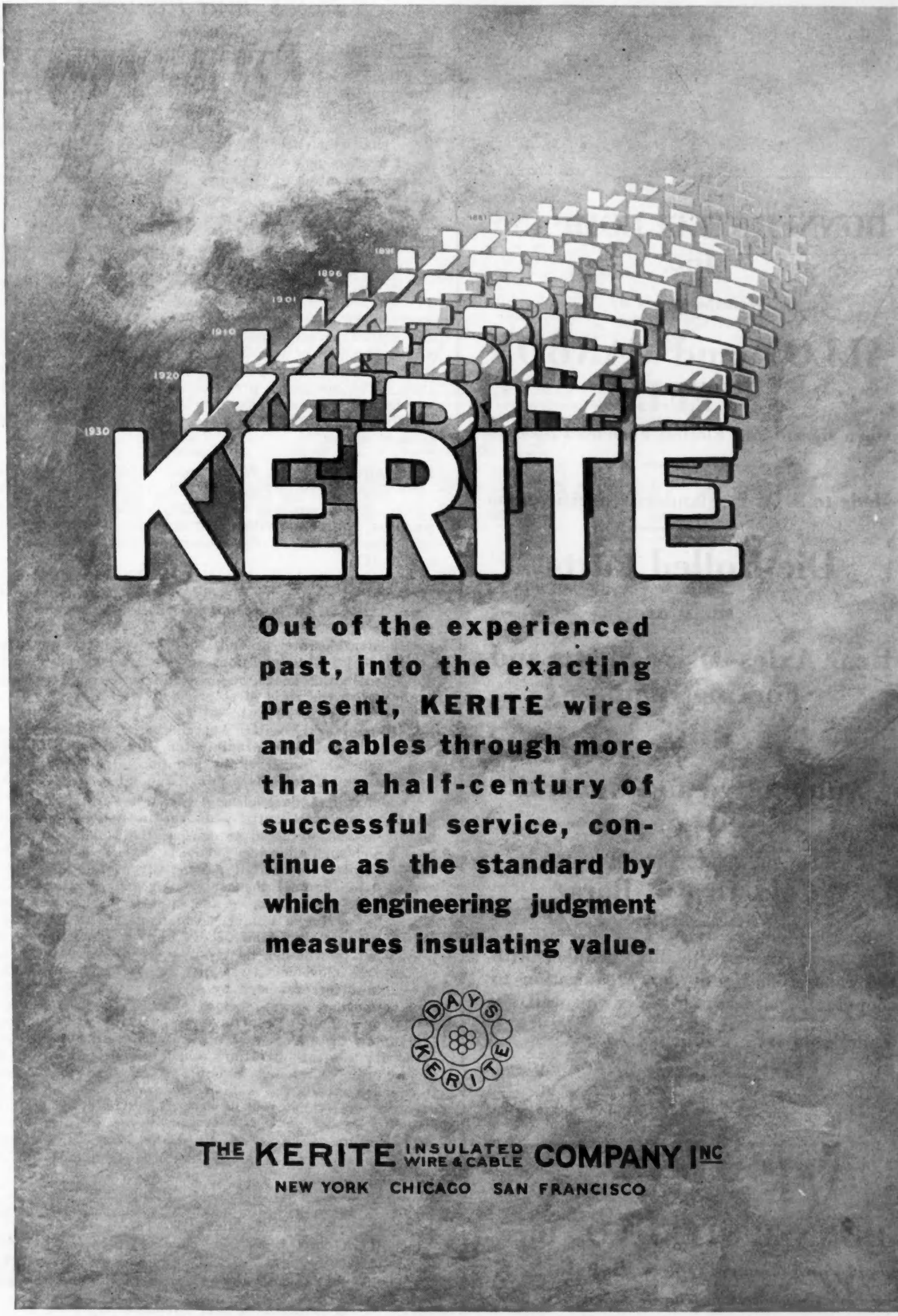
The models were made up of standard 3 x 18-in. duralumin airfoils and fuselages of wood. The airfoils employed in the investigation were (*a*) R.A.F.-15, a thin section; (*b*) U.S.A.-27, a section of medium thickness; and (*c*) Gottingen-387, a thick section. Three fuselages were used, one of streamline form, one of cabin form and one of open-cockpit form.

A number of typical monoplane and biplane combinations of wings and fuselages were tested, and in some cases the effect of fairing between wings and fuselage was studied.

The results of the investigation indicate that the interference effects are dependent on the shape of the fuselage, the airfoil section and the relative position of the fuselage and airfoil. The better the aerodynamic form of the fuselage and the thicker the airfoil section are, the greater are the interference effects and the more marked the influence of the relative vertical position of the wings and body on the interference.

Interference between wings and body tends, in general, to lower the critical angle and increase the drag of the combination as compared with the individual components. It may increase or decrease the lift.

(*Continued on next left-hand page*)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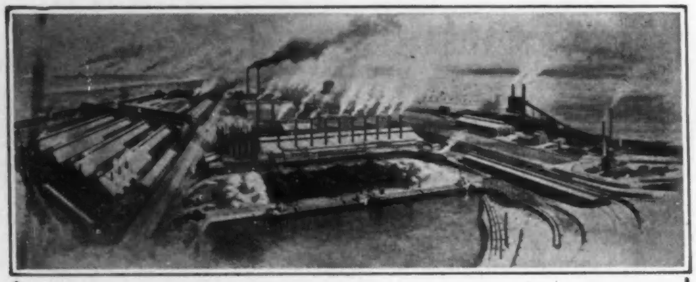

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Notes and Reviews

Continued

From an aerodynamic viewpoint, the best position for the wing is at the top of the fuselage, and the worst is at the bottom.

Fillets and fairing may improve a combination having poor characteristics, but have little effect if the arrangement already possesses good characteristics.

An explanation of the cause of the observed interference effects is advanced.

Undercarriage Developments. By George H. Dowty. Published in *The Journal of the Royal Aeronautical Society*, February, 1930, p. 170. [A-1]

The subject is considered from the aspect of reducing to the minimum, as far as possible, the weight and resistance of the undercarriage component, and toward this end the author makes numerous suggestions for possible lines of development of wheels, shock-absorber legs, compression rubbers, brakes and other parts of the undercarriage structure. The conclusion predicts improvements to the undercarriage during the next few years that will reduce its resistance to one-half and its weight to two-thirds their present values.

Rigid Airships. By E. W. Stedman. Published in *The Engineering Journal*, February, 1930, p. 104. [A-1]

The author outlines the history of airship design and progress, beginning with the first rigid airship and ending with descriptions of the modern British airships R.-100 and R-101.

The theoretical considerations which enter the design of the rigid airship are briefly considered under the headings, Aerostatics, Hull Design, General Arrangement, and Methods of Construction.

Considerable interest and value are added to the article by the wealth of illustrations and the bibliography which is appended listing books, reports and articles in periodicals dealing with the rigid airship.

Ermittlung der Grössten Aufbringbaren Steuerkräfte und Erreichbaren Geschwindigkeiten der Steuerbetätigung. By Heinrich Hertel. Published in *Zeitschrift für Flugtechnik und Motorluftschiffahrt*, Jan. 28, 1930, p. 36. [A-1]

To determine the loading allowances permissible in the design of aircraft control-gear, the investigation described in this article, designed to disclose the fundamental facts upon which such allowance should be based, was undertaken.

The greatest force that a normally strong man can be expected to exert at the controls in the operations necessary for elevation, banking and lateral steering was determined by testing a number of persons. The influence of fatigue, length and kind of exertion, and position of the pilot, that is whether he is strapped to his seat or permitted free movement, was investigated. The average of the highest force exerted by all persons for each type of control movement was decided upon as the best figure to adopt for amount of control force normally to be expected.

Dynamic tests also were made to determine the greatest speed for control operations under conditions calling for the exertion of various amounts of force at the controls. During these tests the loading was varied from zero to the greatest force that could be exerted by the subjects of the investigation.

The results of the series of tests are given in detail and, general conclusions, said to be possible because of the uniformity of the results, are drawn.

Airplane Mechanics Rigging Handbook. By R. S. Hartz and Elzor E. Hall. Published by The Ronald Press Co., New York City, 1930; 254 pp., illustrated. Price $3.50. [A-2]

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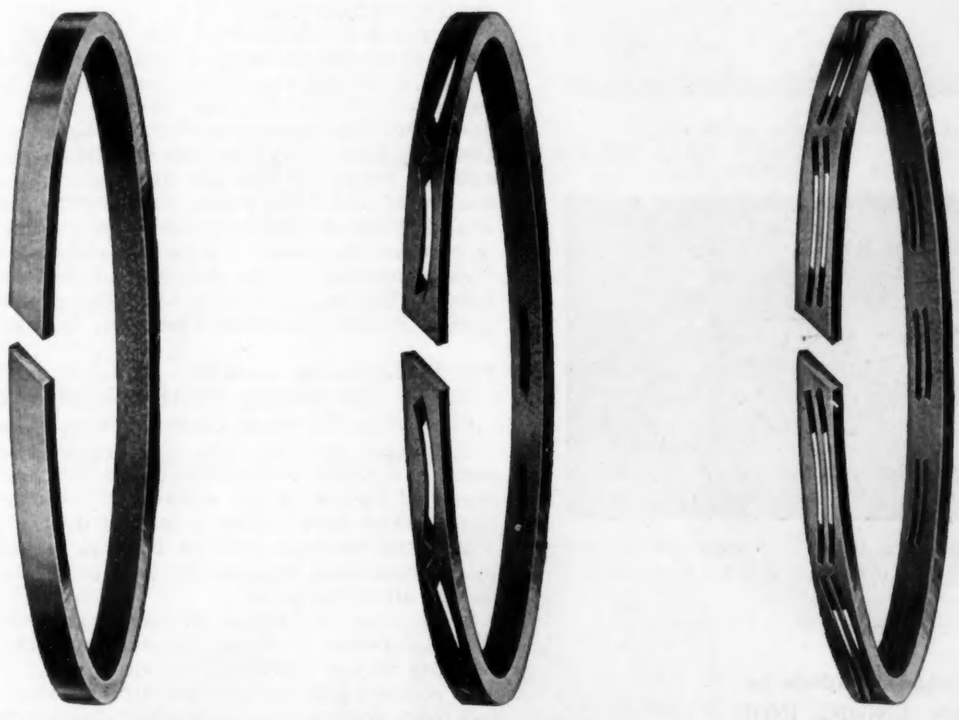

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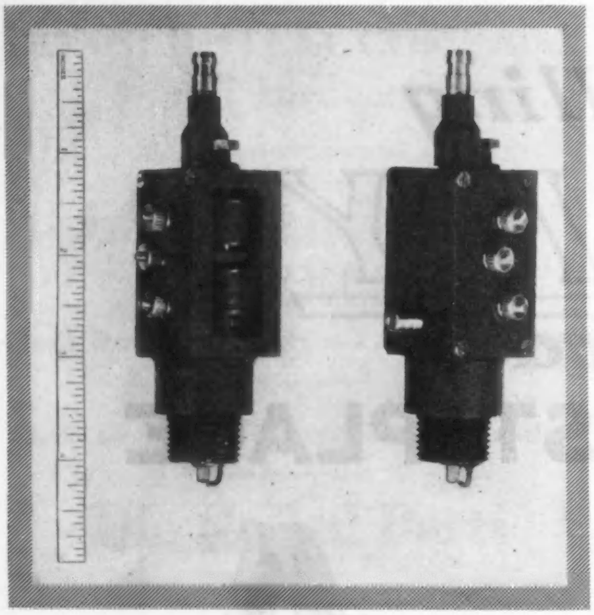
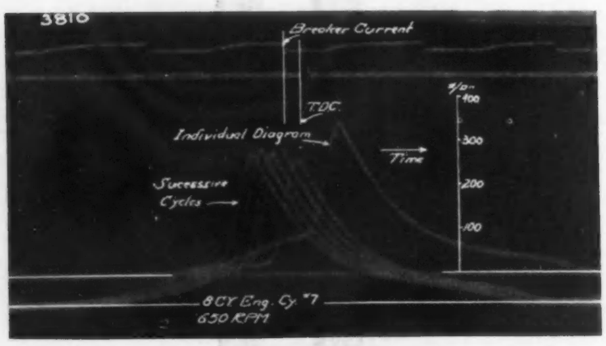


The electric engine indicator spark plug.



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Notes and Reviews

Continued

ous problems of maintenance that comprise the daily tasks of the airplane mechanic. No attempt is made to present the theory of aeronautics. The authors emphasize the responsibility of the mechanic's position and urge the employment of the greatest care, accuracy and thoughtfulness in repair work.

The detailed procedure for the welding, riveting, heat-treating and repairing of aluminum alloys that are coming into use for the wings of all-metal airplanes is not covered in this book because of the amplitude of the subject and the fact that several books on welding have appeared recently which furnish the necessary material for such work.

Chapters cover general instructions, definitions, and important principles; rigging airplanes; the maintenance of struts, spars, and fabric; controls; and inspection hints. The selection and use of wood, metal parts, wire, dopes and equipment are also treated, with special chapters on the installation and correction of compasses and the care and packing of parachutes.

How to Fly. By Lieut. Barrett Studley, U.S.N. Published by The Macmillan Co., New York City, 1929; 288 pp. and index. Price, $3.00. [A-4]

Lieutenant Studley will be remembered as the author of *Practical Flight Training*, a book published in 1928 and intended primarily for the use of students actually under instruction. Although based on the same fundamental principles as the earlier work, the present volume is less technical, including only the more immediate and practical details of application.

In the first chapters of the book a brief summary is given of the development of aviation and the men who took a leading part in shaping the early history of the industry. In the chapter on Why an Airplane Flies, the author sets down the rules governing flight, diagrams the parts of a plane, explains their functions and defines the more common aviation terms. From this he goes to a consideration of modern airplane and engine construction, the qualifications of a pilot and the course at a modern training school. Finally, he takes the reader into the air and gives him the actual flight sensation in the chapters which follow: The First Lesson; Turns; Take-offs; Landings, Spirals, Stalls and Spins; Stunts; Precision Landings, and so forth.

The Navigation of Aircraft. By Lieut. Logan C. Ramsey, U.S.N. Published by The Ronald Press Co., New York City, 1929; 223 pp. and index. Price, $4.50. **[A-4]**

Lieutenant Ramsey, who is a recognized authority on aerial navigation, declares that avigation has been the most neglected branch of the science of aeronautics, a circumstance which he explains is largely due to the belief that it involved virtually nothing but the use of astronomical observations and was needed only on a few of the spectacular air voyages.

In the book, the author points out that aerial navigation is a vital factor in efficient airplane-operation, the methods differing only in flights of various length. He asserts that dead reckoning is the most important branch of the science and most deserving of attention from all fliers and navigators.

Methods and systems unsuitable for use in heavier-than-air craft have been omitted.

Curtiss Tanager, Judged the Safest Aircraft in Guggenheim Contest. By A. B. Crofoot. Published in *Automotive Industries*, Jan. 18, 1930, p. 90. **[A-4]**

The winner of the $100,000 prize given by the Daniel Guggenheim Fund for the Promotion of Aeronautics in its Safe Aircraft Contest is described and the characteristics and detail measurements are given in both tabular and drawing form.

A brief outline of the qualifying tests is included in the

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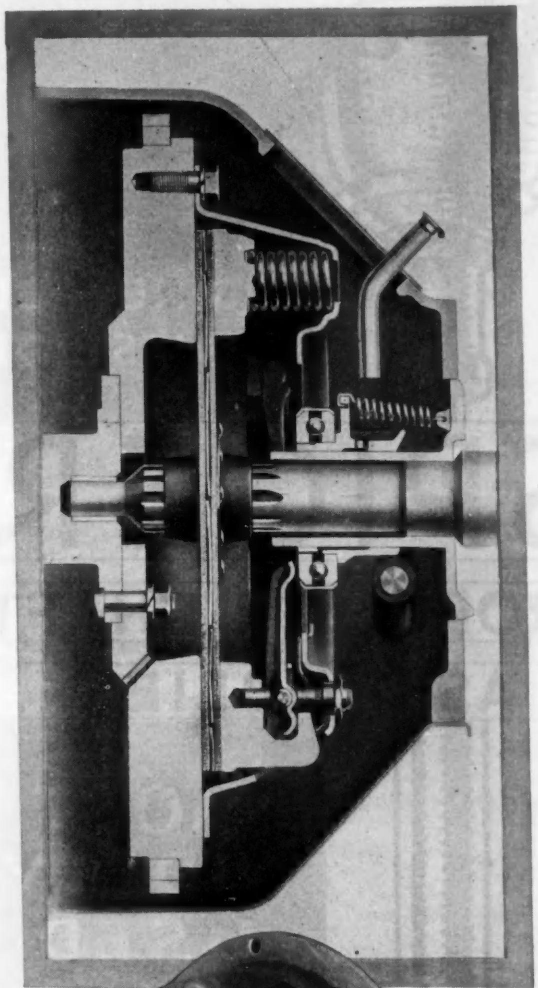

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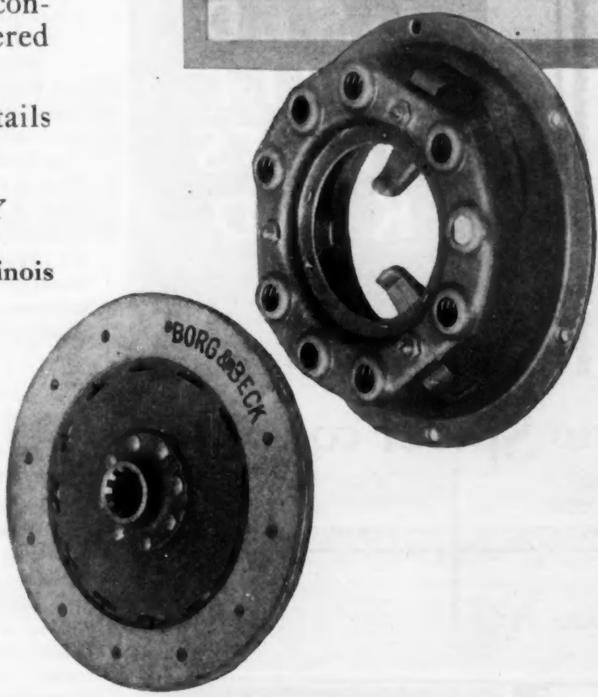

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Notes and Reviews

Continued

article, and it is pointed out that the Curtiss airplane was the only entrant that passed all of them.

Basically, the Tanager is a three-place cabin biplane, departing from conventional biplane design by the addition of three safety devices; namely, a floating aileron, automatic wing-slots and controllable wing-flaps. Furthermore, the machine was so designed that it could be placed in production with a minimum of changes and with a slight change in the ordinary engineering practice.

CHASSIS PARTS

Petrol-Electric Vehicle Characteristics. By H. K. Whitehorn. Paper presented before the Institution of Automobile Engineers, London, January, 1930. [C-1]

The author has collected the leading particulars of 25 gasoline-electric systems, some of which have been tried. He lists as the reasons that have prevented the various systems from becoming prominent: (*a*) inability to overdrive, (*b*) inability to free-wheel, (*c*) use of a battery to assist propulsion, (*d*) use of gearing for intermediate speed-changes, (*e*) fear of electrical losses on top speed for which a synchronizing clutch is used, (*f*) propulsion control effected by continual movement of the brush holders on the electrical machines, (*g*) use of resistances in the main circuit, (*h*) inability to reverse electrically.

The paper discusses in detail the Tilling-Stevens system and aims to remove doubts about the practicability of gasoline-electric propulsion.

Comparaison des Differents Types de Bandages Utilisables sur les Véhicules Industriels. By J. Delpeyroux. Published in *Le Génie Civil*, Jan. 11, 1930, p. 33. [C-1]

A comparison is made between the merits of solid and pneumatic tires as applied to industrial vehicles, and the Pirelli is described as a typical cushion, designed to act as a compromise between solid and pneumatic tires. A summary is made of investigations designed to throw light on the effect of different types of tire on highways. Among the researches so noted are those of the United States Bureau of Public Roads; those of Quervain, Bonfils, and Auclair and of Boyer-Guillon in France; those of the Studien-Gesellschaft für Automobilstrassenbau and Langer and Thomé in Germany; and finally those of Parducci and Vandone in Italy.

The question of legislation on tire usage is taken up next. At present, France does not differentiate between solid and pneumatic tires, so far as taxation is concerned, but does impose a lower speed on solid-tired vehicles. Proposed legislation is summarized and criticized.

ENGINES

Die Entwicklung der Junkers-Diesel-Flugmotoren. By Dr. Ing. Gästerstadt. Published in *Automobiltechnische Zeitschrift*, Jan. 10, p. 2, and Jan. 20, 1930, p. 41. [E-1]

The development of the various design and constructional features by means of which the Junkers company endowed its Diesel aircraft-engine with the requisite characteristics of such a powerplant, that is, high speed and low weight, is here traced in interesting detail.

The author points out that, even in the first Junkers Diesel engine, a stationary plant brought out in 1915, are found the fundamentals upon which the aircraft engine depends: the opposed-piston two-crank system, airless injection, and scavenging by means of spiral air currents. The extent of the improvement in performance and efficiency that has been effected by the refinements incorporated during the succeeding 14-year period is graphically shown in a diagram giving, for an early stationary engine, an automotive engine and an aircraft engine, all Diesels, the

(*Continued on next left-hand page*)

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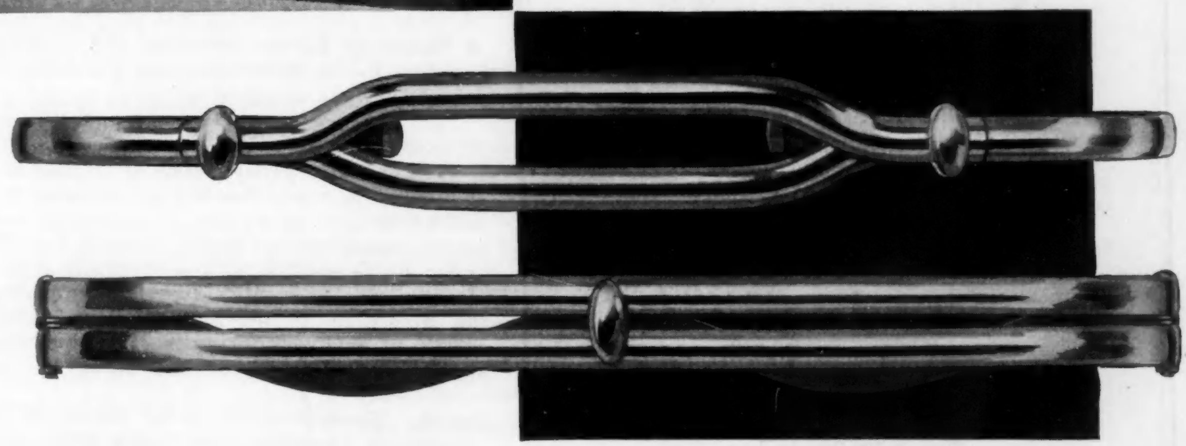

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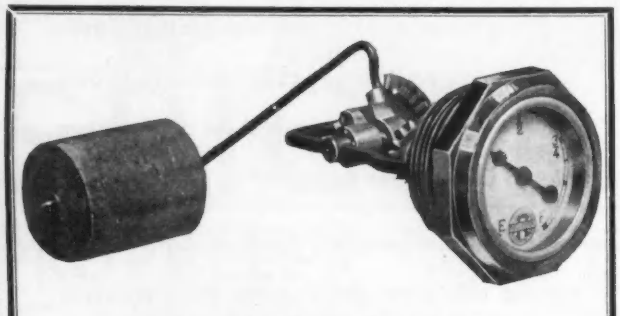

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Notes and Reviews

Continued

performance per displacement, the piston speed and the weight. This shows a successive increase in horsepower per liter (61.02 cu. in.) displacement of from 6 to 16 to 21; in piston speed in meters per second of from 3.3 to 6 to 11 (10.82, 19.68, 36.09 ft.); and a decrease in weight per horsepower of from 27 to 7 to 1.4 kg. (44.09, 15.43, 3.08 lb.).

Having thus graphically contrasted the old and the new, the author sets forth the steps that led from the one to the other, covering in turn various research projects on the combustion process and the equipment designed to facilitate it, the driving gear and general construction, and the application of the engine to aircraft. Some of the points covered are the fuel-injection pump, scavenging system, supercharger, temperature control, crankshaft vibration and stresses, engine housing and mounting. He summarizes the accomplishments of the Junkers Diesel engine by pointing out that it has been operated 50 hr. in an airplane in flight, the longest sustained flight being 8 hr., and that the total weight at starting was 4700 kg. (10,361 lb.), the load on the engine being 7.5 kg. (16.53 lb.) per hp.

Spark-Plug Terminal Material Is Factor in Performance. By Hector Rabezzana and Donald W. Randolf. Published in *Automotive Industries*, Jan. 18, 1930, p. 83. [E-1]

In an investigation of ignition miss, the A.C. Spark Plug Co. has made an extended study of the electrical characteristics of the ignition system in engine operation. This research and development work have brought about a better understanding of the subject which has resulted in an improved material for spark-plug electrodes.

A brief summary of the factors affecting the secondary potential and the break-down or sparking voltage of plugs under operating conditions is set forth, with accompanying curves showing typical characteristics.

To minimize spark-plug missing, the following points are recommended: (*a*) small spark gap, from 0.015 to 0.018 in. in high-compression engines, and from 0.018 to 0.022 in. in low-compression engines; (*b*) electrode shapes least affected by corrosion, that is, no sharp edge or points at the gap; (*c*) good electrode wire; (*d*) correct carburetion; (*e*) proper spark-plug position in the combustion-chamber; (*f*) correct breaker-point gaps; (*g*) clean and square breaker points; (*h*) correct spark-plugs for the condition under which the engine is used; and (*i*) avoidance of metal shielding on secondary leads and reduction of lead length to the minimum necessary.

A Recording Torque Indicator. By G. R. Anderson. Published in the *Journal of the A.I.E.E.*, December, 1929, p. 865. [E-1]

The measurement of torque under unstable conditions of speed is usually extremely difficult and inaccurate when a dynamometer, prony brake or similar torque-measuring equipment is used, the author declares. The device described in this paper was developed primarily to obtain torque measurements under unstable conditions as well as under stable conditions, and to obtain a permanent record of these measurements. It has been particularly successful, according to the report, in recording speed-torque curves of engines during acceleration and can also be applied very effectively to other fields.

Rapidly Fluctuating Pressure Measured Electrically by Indicator Combined with Spark-Plug. By E. J. Martin and D. F. Caris. Published in *Automotive Industries*, Feb. 15, 1930, p. 230. [E-1]

An indicator almost entirely electrical in its operation and which produces its records by means of an oscillograph was developed about two years ago by the General Motors Research Laboratories and described in the July, 1928, issue of the S.A.E. JOURNAL.

(*Continued on next left-hand page*)

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Years ago when motor cars were in the experimental stage Stromberg was experimenting, too, with an automobile carburetor. One that would be dependable—that would fuel the engine at all speeds, under all conditions, efficiently and economically.

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The automobile world quickly recognized the remarkably fine performance of Stromberg carburetors. The result is that today most leading manufacturers use Stromberg carburetors as standard equipment. And as the industry grows and new cars and engines are developed, builders turn inevitably to Stromberg for the solution of their carbureting problems.

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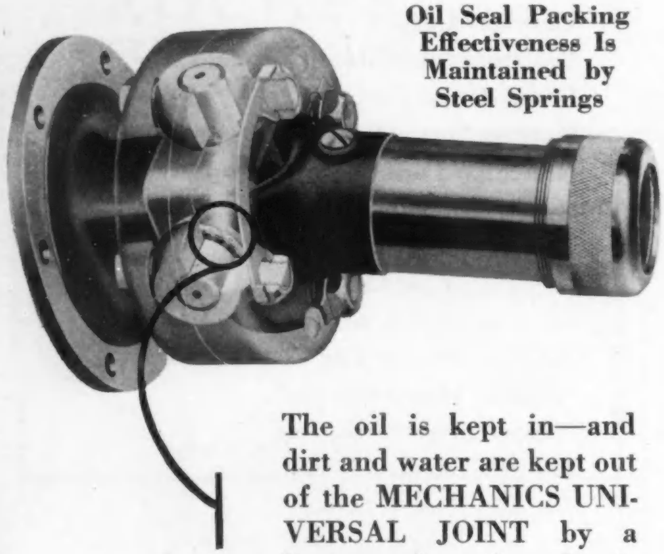

The oil is kept in—and dirt and water are kept out of the MECHANICS UNIVERSAL JOINT by a heavy cork washer that is protected from spreading or cracking, when compressed between the housings, by a brass ferrule. A steel spring keeps the cork washer flush against the shoulders of the yoke trunnions at all times, thus taking up any possible wear of the cork.

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Notes and Reviews

Continued

The article under review gives a brief description of the working principles of this device and explains in considerable detail, with the aid of numerous photographs from the indicator record, recent developments and improvements embodied in the indicator.

Carbureters, Gasoline Fuel-Feed Systems, Air-Cleaners, Superchargers, Ricardo Cylinder-Head, Engine Bearings. By A. L. Dyke. Published by The Goodheart-Willcox Co., Inc., Chicago, 1929; 105 pp., illustrated. [E-3]

This volume has been issued as a supplement to Dyke's Automobile Encyclopedia and follows the style adopted for that book. The title indicates the engine parts covered and the book's chief value is for reference in maintenance work. A detailed index greatly facilitates the use of the book.

Design and Application of Rail Motor-Cars. By Charles O. Guernsey. Paper presented at the Annual Meeting of the American Society of Mechanical Engineers, Dec. 2 to 6, 1929, New York City. [E-4]

The rail-car is capable of performing certain services to better advantage than motive power of any other current type, the author contends, but is not a competitor of the locomotive in the locomotive's proper field. It is capable of performing services within its scope at a cost and with an availability and reliability at least equal to that of other railroad equipment. Mr. Guernsey states that satisfactory operation depends on correct design, correct application, proper handling by the operators and intelligent and thorough maintenance.

This paper gives the field for application of rail-cars, some problems of design and use, and conclusions as to design, operation and maintenance.

MATERIAL

Utilisation des Gaz Combustibles pour l'Alimentation des Moteurs de Poids Lourds. By Col. Lucas-Girardville. Published in *Journal de la Société des Ingénieure de l'Automobile*, December, 1929, p. 842. [G-1]

The author, president of the National Fuels Section of the Automobile Club of France, who has been interested since the close of the World War in the development of an indigenous French automotive fuel, reviews the yearly motorcades organized by the Automobile Club of France for the demonstration of such fuels.

These events have brought into notice four classes of such fuels that do or can be made to provide satisfactory operation; those derived from agricultural products, from wood, from coal or synthetic fuels. Of these only two can be called national, in the sense of being available in sufficient quantity to replace France's yearly gasoline consumption of 1,400,000 tons. These are wood, used in the form of charcoal in a gas producer, and gas derived from coal. The bulk of wood presents an impediment in handling, which is an obstacle to its use, particularly in military transport. The choice is thus narrowed down to gas.

Three types of gas are available: city and coke gas, which are approximately the same, and methane. The two former are rated at 4500 calories per cubic meter (1.308 cu. yd.) and the last at 9500 calories. The author takes up the practical aspects involved in the use of gas as a motor fuel, such as price, safety from explosion, design of tanks sufficiently strong for carrying the gas and yet light, the apparatus that needs to be installed in an engine that is to use gas as fuel, and the transportation of the gas from the centers of production to the points of usage.

The Gaseous Explosive Reaction at Constant Pressure—The Reaction Order and Reaction Rate. By F. W. Stevens. Report No. 337. Published by the National Advisory Committee for Aeronautics, City of Washington, 1930; 16 pp. [G-1]

(Continued on second left-hand page)

. . . Denatured Alcohol PREVENTS COOLING SYSTEM TROUBLES . . . .

MOTORISTS *are not bothered by cooling system troubles when Denatured Alcohol is used. This oldest anti-freeze is harmless, non-corrosive and insures efficient cooling at lowest temperatures.*

WHEN Denatured Alcohol solution is drained from their cars at the end of the season, motorists forget about anti-freeze until snow flies again. No springtime cooling problems bother those 20,000,000 motorists who have used Denatured Alcohol.

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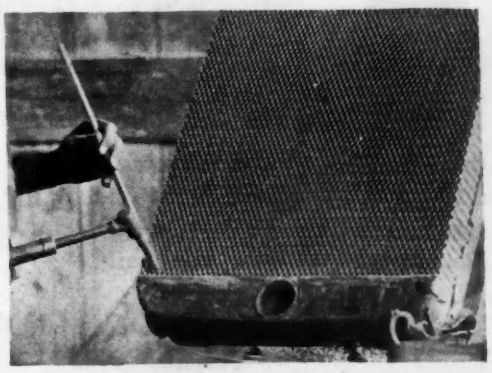

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Notes and Reviews

Continued

The Relation Between the Tensile Strength and the Hardness of Metals. By O. Schwarz. Translated from *Zeitschrift des Vereines deutscher Ingenieure,* June 8, 1929, Technical Memorandum No. 552; 15 pp., 16 figures. [G-1]

Experimental Investigations Concerning the Limits of Detonation in Gaseous Mixtures. By Rudolf Wendland. Parts I and II. Translated from *Zeitschrift für Physikalische Chemie,* 110, 637, (1924), and 116, 227, (1925). Technical Memoranda Nos. 553 and 554, 25 pp., 4 figures, and 47 pp., 4 figures, respectively. [G-1]

The Boundary Layer as a Means of Controlling the Flow of Liquids and Gases. By Oskar Schrenk. Translated from *Die Naturwissenschaften,* Vol. 17, No. 34, Aug. 23, 1929. Technical Memorandum No. 555; 22 pp., 8 figures. [G-1]

The foregoing technical Report and four Technical Memoranda were published during February by the National Advisory Committee for Aeronautics, City of Washington.

Chemistry of Gum Formation by Cracked Gasoline. By LeRoy G. Story, Robert W. Provine and H. T. Bennett. Published in *Industrial and Engineering Chemistry,* November, 1929, p. 1079. [G-1]

A detailed study made of gum formation by cracked gasolines is reported in this paper. The dish test is described and the factors influencing the test discussed. The changes taking place in cracked gasoline during evaporation and the composition of the gum deposited are given, together with the results of an investigation of the absorption of oxygen and the formation of gum when gasolines are exposed to sunlight.

From this research the authors deduce that the formation of gum by evaporation of a cracked gasoline is a result of the oxidation of unsaturated hydrocarbons. These hydrocarbons are of a type relatively active, which are readily polymerized and removed by sulphuric acid. The products of the oxidation, it is stated, appear to be initially peroxides, with acids as the chief end-products making up the gum.

A theory of gum formation, involving primarily autoxidation, is offered.

Le Métallographie par les Rayons X. By M. Mathieu. Published in *Le Génie Civil,* Jan. 4, 1930, p. 1. [G-1]

After tracing briefly the progress of X-ray examination as an instrument of general research, the author narrows his treatise down to the specific field of the X-ray examination of metal. Three purposes that X-rays may serve are pointed out: the detection of major imperfections, the study of crystalline structure and the investigation of the effects of mechanical working and heat-treating.

Under the first heading, a method for the quantitative measurement of defects is described. Under the second, methods of X-ray use are outlined and the extent to which X-ray studies, coordinated with other methods of investigation, have and may continue to broaden metallurgic knowledge is indicated. In dealing with the third mission of X-rays, the author sets forth the present state of the art. He points out that the mechanical and thermodynamic working of metal affects its structure in two ways, altering the arrangement of the crystals and changing the crystals themselves. Confusion formerly existed as to the exact nature of these alterations. A method by which the effects wrought on metal by mechanical working and heat-treating can be clearly distinguished is outlined. Descriptions of numerous X-ray instruments of French manufacture are given.

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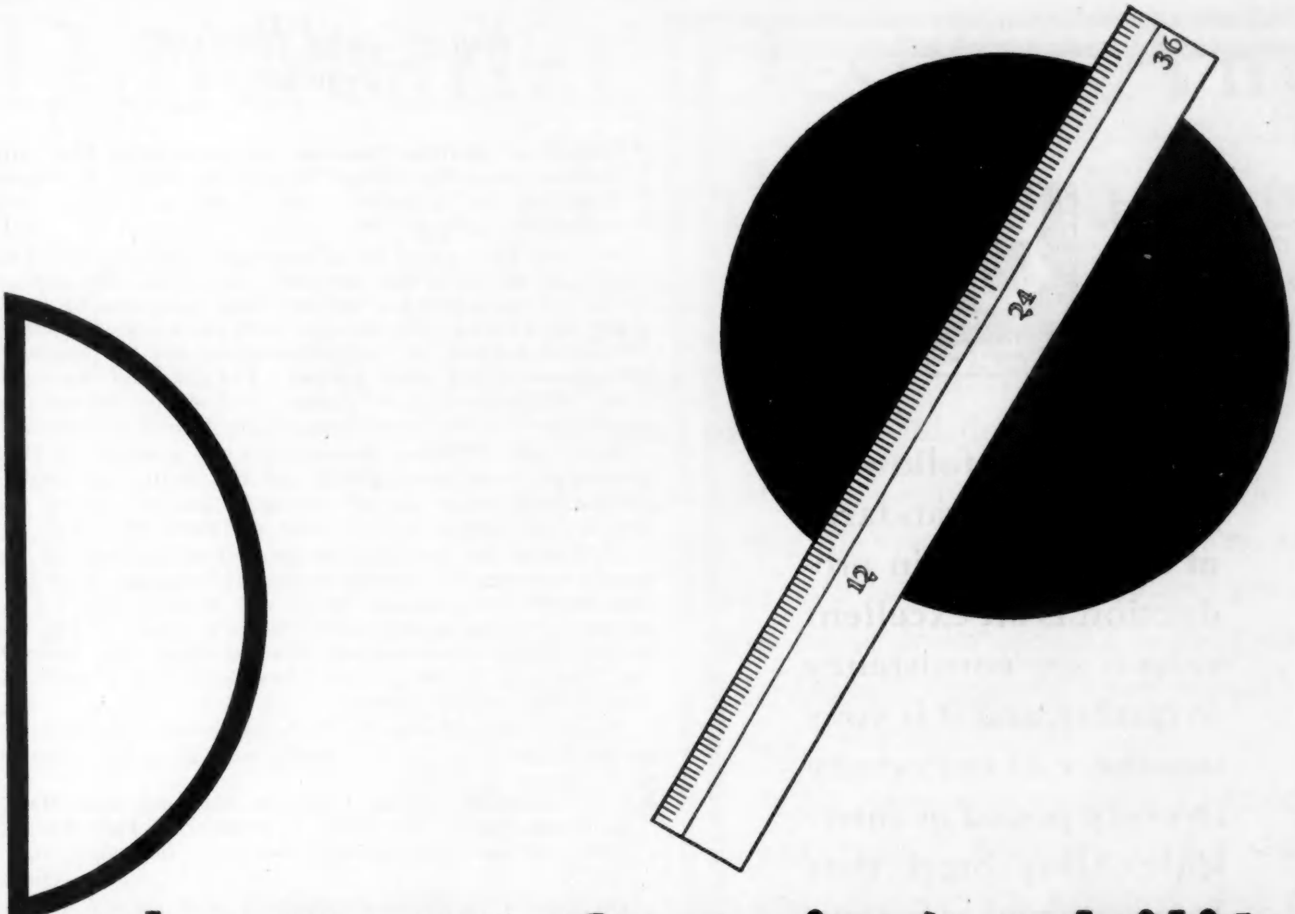

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Notes and Reviews

Continued

Variation of Surface Tensions of Lubricating Oils with Temperature. By George Winchester and R. K. Reber. Published in *Industrial and Engineering Chemistry*, November, 1929, p. 1093. **[G-1]**

It is well known that the effectiveness of oils as lubricants diminishes rapidly at high temperatures. What part surface tension plays in this has hitherto been impossible to determine, the authors point out, yet such knowledge has direct industrial bearing on both lubrication and the capillary phenomena of oils under ground. The theory of the maximum bubble-pressure or Jaeger method for determining the surface tension is explained and the apparatus described.

Eight oils, differing considerably in general physical properties, were investigated, and the results of characteristic tests made by oil companies as well as of the density and surface-tension tests are given in tables.

As far as the investigation goes, it shows that, if the density temperature curves of two oils coincide, their surface-tension temperature curves will coincide also. Furthermore, if the density curves do not coincide, then the surface-tension curves do not have the same slope, indicating that some property other than density is effective in determining surface tension.

The authors call attention to a difference of opinion regarding the nature of the dependence of surface tension upon density.

Recent Developments in Corrosion-Resistant and Heat-Resistant Steels. By John A. Mathews. Published in *Industrial and Engineering Chemistry*, December, 1929, p. 1158. **[G-1]**

The paper presents data concerning, first, certain factors affecting ordinary corrosion at ordinary temperatures, and, second, the type of corrosion more familiarly called oxidation or scaling, which occurs at high temperatures. The condition is also considered under which the two are combined in a single problem where the corrosive action of the products of combustion must be considered, or in some cases one side of the metal may be subjected to heat and scale and the other side subjected to ordinary chemical attack.

The writer of the article foresees endless applications for alloy steels possessing these corrosion and heat-resistant properties.

MISCELLANEOUS

Power Required to Drill Cast Iron and Steel. By O. W. Boston and C. J. Oxford. Paper presented at the Annual Meeting of the American Society of Mechanical Engineers, Dec. 2 to 6, 1929, New York City. **[H-5]**

This paper presents the results of drilling tests on cast iron and steel. Drills ranging in diameter from ½ to 1½ in., of the standard twist-drill type, were used. They were considered sharp in all tests. A coolant consisting of 1 part of soluble oil and 16 parts of water was used in all tests. The materials cut consisted of one regular machining cast iron and one cast iron made up of 20 per cent charcoal pig-iron, together with 17 steels of a wide variety of chemical analyses, which were selected to cover the steels commonly used in modern manufacture.

Data as to drilling torque, thrust, computed horsepower at the drill point, and net horsepower supplied to the machine as measured on a recording wattmeter are given under two headings: commercial tests and special tests.

Special tests were run on various cast irons and steels so that the influence of the speed, feed and drill diameter could be determined.

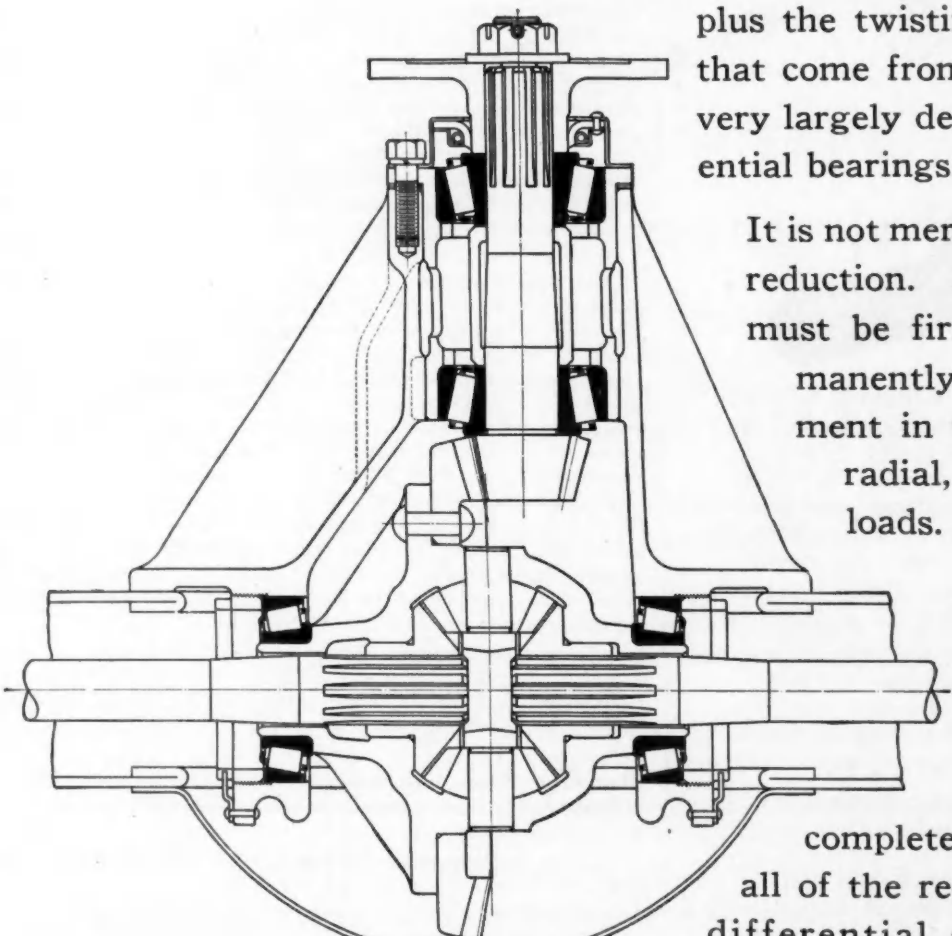
An attempt is made to correlate the hardness values of the materials, as determined by the Brinell, Rockwell, scleroscope and Herbert pendulum hardness-testers, with the results obtained from the drilling tests.

(Continued on next left-hand page)

Differential Design And Timken Bearings

Selecting anti-friction bearings that have the ability to provide proper and permanent support for the differential unit is of major importance in differential design.

A quiet rear axle, and one that can hold its own under the high torque of modern motors plus the twisting strains and shocks that come from today's high speeds, very largely depends upon the differential bearings.



It is not merely a matter of friction reduction. Axle and pinion shafts must be firmly gripped and permanently held in rigid alignment in the face of the severe radial, thrust and resultant loads. Correct gear contact must be maintained under all conditions of speed and road.

There is one bearing that is inherently and completely capable of meeting all of the requirements of efficient differential service—Timken—because of this exclusive combination of advantages: Timken tapered construction, Timken *POSITIVELY ALIGNED ROLLS* and Timken-made steel.

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Notes and Reviews
Continued

Conclusions reached are that no satisfactory relation exists between these properties and that machinability constants for any material would have to be determined from actual drilling tests. From the data available the authors deduce that the type of steel, the carbon content and the microstructure are all very important factors in the determination of this machinability factor.

Turning with Shallow Cuts at High Speeds. By H. J. French and T. G. Digges. Paper presented at the Annual Meeting of the American Society of Mechanical Engineers. Dec. 2 to 6, 1929, New York City. **[H-5]**

In this paper a method is described for testing lathe tools under shallow cuts and fine feeds. The relations are determined between the cutting-speed, feed depth of cut, and tool life for carbon and high-speed tool steels. Comparisons are made of tools of different forms and of tool life when cutting dry and with water or lard-oil. Heat treatment and chemical composition of the tools are also studied, including in the case of high-speed tool steels the effects of cobalt, nickel-molybdenum, arsenic, antimony, phosphorus, sulphur, copper, tin, aluminum, titanium and tantalum. The results obtained under shallow cuts and fine feeds with these steels are compared with those obtained under heavy duty.

Present Practice in the Use of Cutting Fluids. By S. A. McKee. Paper presented at the Annual Meeting of the American Society of Mechanical Engineers. Dec. 2 to 6, 1929, New York City. **[H-5]**

This paper constitutes the second progress report of the Subcommittee on Cutting Fluids of the A.S.M.E. Special Research Committee on Cutting of Metals. An effort is made to indicate either the trend or lack of trend, as the case may be, toward the use of a particular type of cutting agent for a given machining operation on a given kind of metal, based on information obtained from 68 of the large users of cutting fluids in this Country. Nine tables are presented. The first of these is a general summary. It lists the number of plants using any of three general types of cutting agent (dry, water or emulsions, oils or oil mixtures) for each of 19 machining operations on 8 kinds of metal. Each of the remaining tables gives more detailed information pertaining to the cutting agents used for the various operations on a given metal.

Subcommittee D on Properties of Materials of the A.S.M.E. Special Research Committee on Cutting of Metals also presented a report at the same meeting, under the title, Test Code for High-Speed Steel for Turning-Tools.

Über Freie Arbeit und Bandarbeit. By Dr. Heinrich Düker. Published in *Sparwirtschaft*, December, 1929, p. 605. **[H-5]**

In this experimental research into the psychology of work, answers were sought to two questions:

(1) Does continuous production on which there is a strict time control demand, in return for its higher efficiency, a greater output of energy than uncontrolled labor?

(2) If not, what is the psychological reason for the superiority of controlled labor?

Tests were made of controlled and uncontrolled work, both mental and manual, with persons of various ages and callings as subjects. Each person underwent a series of tests extending over periods from 8 to 30 days. The period during which work was performed each day ranged from 10 min. to 6 hr.

Results of certain series of tests, said to be typical of the observations made during the entire course of the research, are given. They tend to show that controlled labor is greatly superior to uncontrolled labor, saving time, producing

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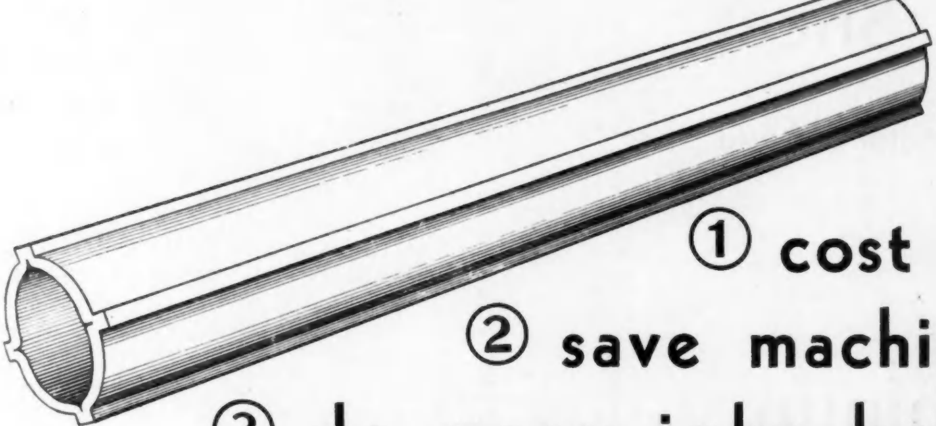

① cost less
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Photograph of cross section of Detroit Integral-Key Shafting with single key.

We have perfected a process for manufacturing hollow shafting with keys integral.

The shafting is cold drawn seamless steel tubing.

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Engineers will readily see many places where this new Integral-Key Shafting can be used profitably.

Its advantages are these:

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Keys can be drawn in one, two, three or four 90° positions, as required. They are guaranteed accurate within the accepted limits of commercial cold-drawing.

If you so desire, our Metallurgical and Engineering Departments will work with you to develop Integral-Key Shafting to meet best your requirements. We solicit inquiries on this new product, and are ready to manufacture immediately within the size ranges mentioned above. Write or call us, or our nearest Sales Representative, for any further particulars.

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Notes and Reviews

Continued

a higher grade of work and lessening the fatigue of the worker. Results obtained from controlled labor are said also to be much more consistent, the efficiency steadily increasing during the course of the work, which is not the case with uncontrolled labor. Controlled labor maintained its superiority even over long daily periods and over a long series of daily periods.

Statements of those tested that they experienced less fatigue while working under a time control were checked and found true. Analyzing this point from both a theoretical viewpoint and the statements of the subjects, the author finds two reasons accounting mainly for this decrease in fatigue: less strain and less will exertion. The author cites a case in which similar observations were made in a practical way of factory workers and warns that controlled labor would lose its superiority if the tempo of the work exceeded the capability of the workers.

MOTOR-TRUCK

Economic Aspects of Gasoline-Operated Commercial Vehicles. By R. E. Plimpton. Paper presented at the annual meeting of the American Society of Mechanical Engineers, Dec. 2 to 16, 1929, New York City. [K-4]

The author discusses the application of motor-trucks operated over public highways to the service of industrial plants. The economic place of the truck is approached from two angles:

(1) Its function in promoting (*a*) the flow of raw and semi-finished material into the factory or plant; (*b*) the movement between plants under a single management or from any of these plants to the warehouses or branches; and (*c*) the final physical distribution to customers or consumers.

(2) The ownership of the trucks engaged in the productive process (*a*) by the industrial plant itself or (*b*) by outside specialists working as contract or common carriers.

Operation and maintenance of "owned" trucks may be assigned to various plant departments or even to a subsidiary company. The conditions affecting the preferred type of control or organization are considered.

In conclusion, the author discusses at some length the growth of motor express and freight companies. He emphasizes their relation to the industrial plants, particularly of the type manufacturing goods shipped in small lots and sold through outlets dealing directly with the general public.

PASSENGER CAR

Ce Qui Manque à la Voiture Moderne. By René Charles-Faroux. Published in *La Vie Automobile*, Jan. 25, 1930, p. 30. [L-1]

What is lacking in the present-day automobile? What should the French public demand in the cars it buys? An answer to these two questions is contained in this article.

Silence in operation should be one of the chief distinctions of the modern engine; crankshaft vibration should be eliminated or damped, valve gears carefully designed and piston tolerances calculated to achieve this end. Oil reservoirs should be provided so that crankcases can be filled by the simple turning of a valve, and cylinder-heads be easily removable for convenience in valve-grinding.

All transmission designs should provide four speeds, easy clutch operation, accessible and easily operated gearshift levers and quiet rear axles. All cars should be equipped with servo brakes and some scheme for counteracting shimmy, such as the Delaunay-Belleville elastic joint replacing one of the fixed points of the forward spring or

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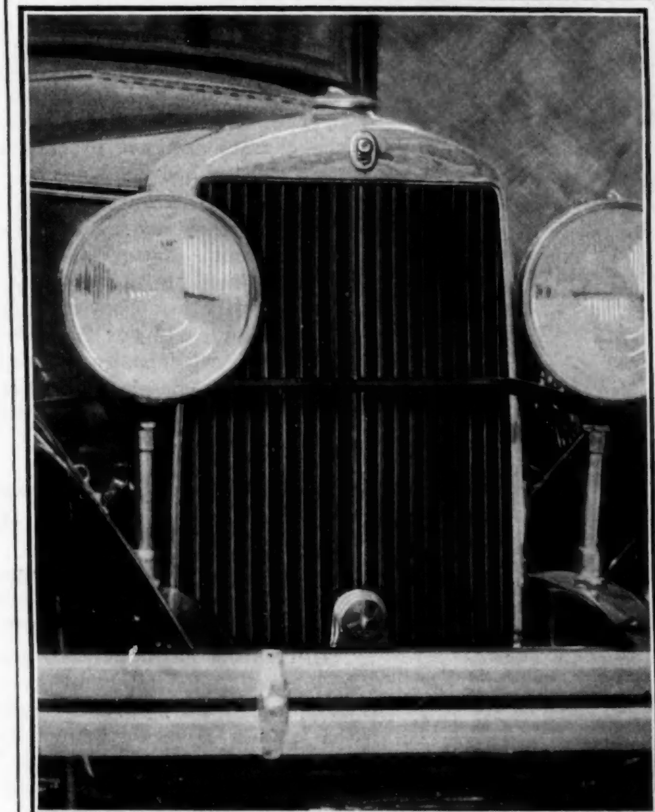

. . . IN DESIGNING AND BUILDING YOUR FUTURE CARS CONSIDER THE AUTOMATIC RADIATOR SHUTTER AS AN IMPORTANT FACTOR IN MAINTAINING YOUR LIST OF CUSTOMERS AND CREATING NEW SALES.

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Notes and Reviews

Concluded

a shock-absorber placed between front axle and chassis. Steering systems should not have too great reduction, should be irreversible and free from play over long periods of operation, and the steering column should be a unit with the chassis and not bracketed partly to the chassis and partly to the body.

Tires and carbureters are dismissed with but little criticism; they are said to have reached a high point of development. Batteries should be of at least 12-volt capacity; favorable mention is made of the system of providing two 12-volt batteries, both of which are used for starting and only one for ignition and lighting. Pressure lubrication with easily accessible outlets is given as the minimum for chassis lubrication, with the centralized, one-shot system for the ideal. Well-fitted tool-boxes are said to be necessary.

L'Automobile en France en 1930. By C. Martinot-Lagarde. Published in *La Technique Moderne*, Feb. 1, 1930, p. 105. [L-1]

This article gives a bird's-eye view of French automotive products and makes suggestions for improving their technical status and commercial prospects.

In treating passenger-cars the author advises that prices be lowered and stricter uniformity of the product be assured as a means for increasing export trade, which is feeling the inroads from the industries of other countries. Passenger models range in power from 5 to 40 taxable horsepower and in price from 15,000 to 150,000 francs. Speed, he states, is still a car characteristic to be sought; not top speed, but high average speed in combination with good driving-qualities, quick acceleration and reliable braking. Car weights, in his opinion, should be still further lessened.

The search for a more smoothly running engine with greater flexibility has led to increase of piston displacement and the lowering of engine speed. A brief review is given of the efforts made to reduce engine vibration and improve valve operation, cylinder-block construction, cooling and lubrication systems, ignition and carburetion.

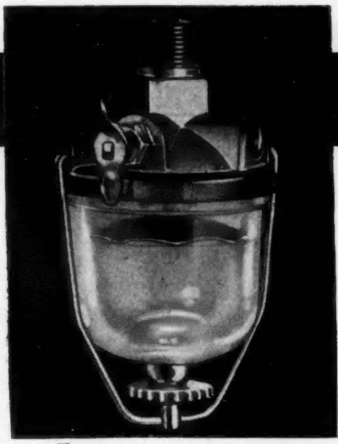
Industrial vehicles are finding a broader field of application as they become more robust and economic. Although gas producers are produced by a number of companies, their use does not increase rapidly. This is attributed not to any technical disadvantage, but to the unwillingness of the drivers to operate a vehicle on which they must handle charcoal and cinders. Diesel engines are enjoying a burst of popularity, the makes available being the Peugeot-Junkers, Sauer, Renault, Morton and the Mercedes-Benz. Front-wheel drive is declared to be losing ground. Attention is given to six-wheel vehicles, dump bodies, trailers and special industrial vehicles.

The Automotive Mechanic's Handbook. By C. T. Schaefer. Published by Harper & Brothers, New York City and London, 1929; 296 pp. and index., illustrated. Price, $4.00. [L-2]

This volume is a compendium of information equally valuable to the garage man and the automobile owner. Trouble charts for diagnosis, instructions for adjustment, suggestions for tests used in shop practice, and statistical data are classified and listed in such a way as to form a handy reference of information necessary in reconditioning the various units and parts of the automobile.

The book is liberally illustrated and adequately indexed.

The author was formerly managing editor of the *Automobile Digest* and has been for many years a member of the Society.



Extra features that make sales

Sales are influenced and often put over by items that add to Economy, Safety and Comfort.

Extra features that demonstrate themselves are:

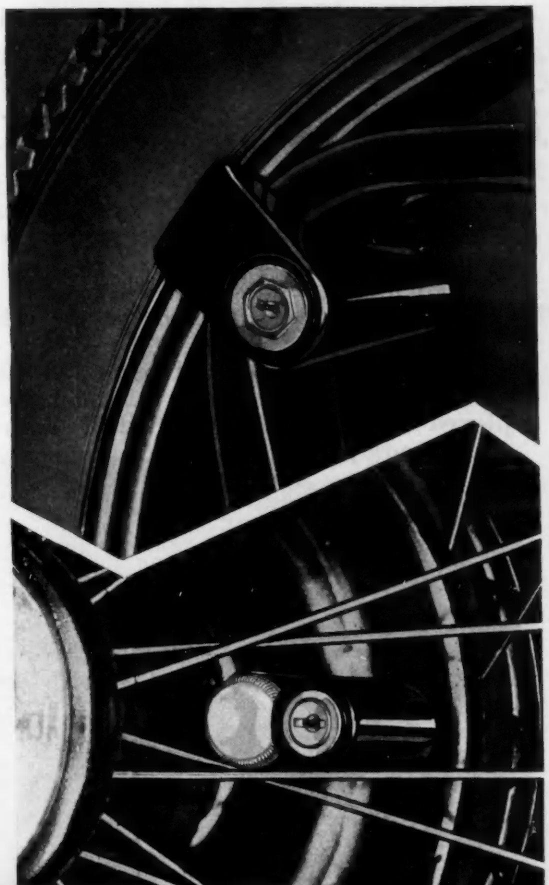
Oakes Gasoline Strainers*—which add to performance and economy.

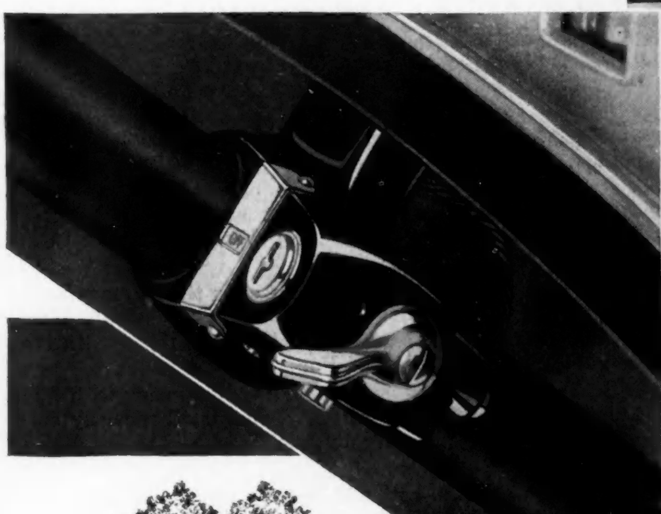
Oakes (Biflex) Window Wings*—which provide comfort winter and summer.

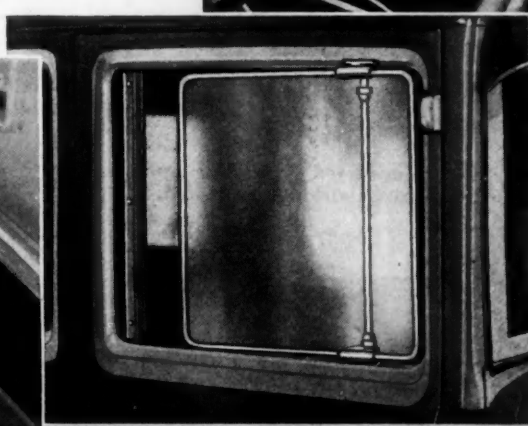
Oakes (Hershey) Steering Post-Ignition Lock*—a convenience and a safeguard.

Oakes Locks* for spare tires and spare wheels—unfailing in strength and distinctive in appearance.

Write for particulars and attractive terms to dealers.







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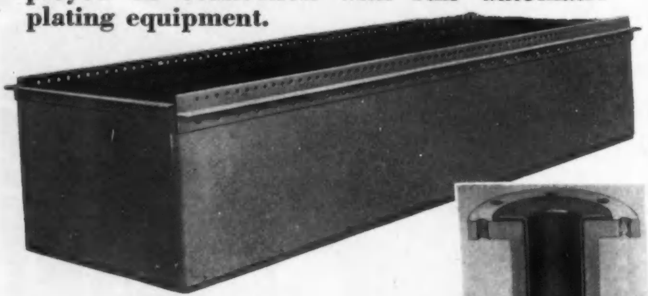
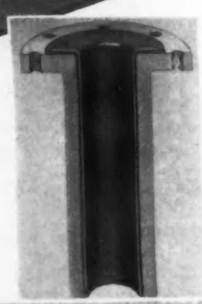
Is Corrosion Proof!

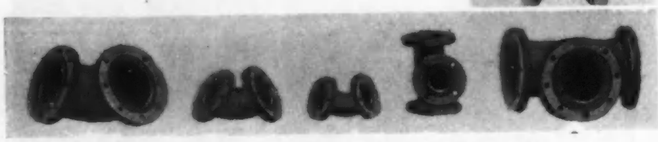
ACE Hard Rubber lined steel Tanks are safe for electroplating and pickling solutions. Equipment lined by the ACE (patented) method resists corrosion; eliminates short circuits and saves valuable current.

The 16′ ACE Hard Rubber lined plating tank illustrated is being successfully employed in connection with full automatic plating equipment.

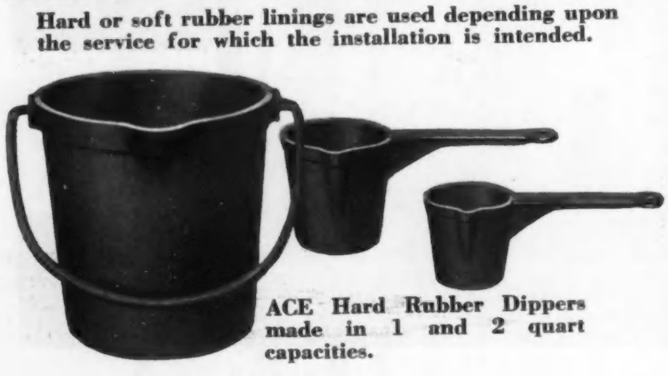




ACE Rubber Lined Pipe and Fittings are regularly supplied in 2 to 10 inch sizes. Larger sizes are available on special order.



Hard or soft rubber linings are used depending upon the service for which the installation is intended.



ACE Hard Rubber Dippers made in 1 and 2 quart capacities.

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Personal Notes of the Members

(*Continued from p.* 525)

ciety matters, having served on numerous committees. It is interesting to note also that he has several times been a member of the executive board of the American Automobile Association.

W. E. Kemp's Promotion

Information has been received that William E. Kemp, formerly Detroit district sales manager of the Kingston Products Corp., of Kokomo, Ind., has been named vice-president in charge of engineering at the company's Kokomo plant. A Personal Note touching upon the main points of Mr. Kemp's history as a Member of the Society appeared on p. 18 of the advertising section of the S.A.E. JOURNAL for April, 1928.

At the recent annual meeting of the American Institute of Mining and Metallurgical Engineers in New York City, **William H. Bassett**, technical superintendent of the American Brass Co., of Waterbury, Conn., was elected president. Among the other officers elected were **Dr. John A. Mathews**, vice-president of the Crucible Steel of America, as a member of the board of directors, and **Zay Jeffries**, consulting metallurgist for the Aluminum Co. of America, as chairman of the Institute of Metals Division. Mr. Jeffries delivered the Howe Memorial Lecture at the meeting, his subject being The Future of the American Iron and Steel Industry.

Under the direction of **F. O. Clements**, technical director of the General Motors Corp. Research Laboratories, in Detroit, and vice-president of the American Society of Testing Materials, a symposium on Developments in Automotive Materials was given at a regional meeting of the A.S.T.M. at Detroit on March 19. Among the contributors to the symposium were **W. H. Graves, Zay Jeffries, Walter C. Keys, H. C. Mougey, Charles Pack** and **R. E. Wilson.**

At the annual meeting of the National Automotive Sales Club in New York City, **Kenneth G. Lydecker**, of the White Co., was elected president. Other S.A.E. Members who belong to the club are **R. D. Dumont**, of the Fink-Dumont-White Co., who was elected vice-president of the club; **S. R. Milburn**, of the B. F. Goodrich Rubber Co., whose term as president of the club expired; **Kilburn D. Clark**, of the Buick Motor Co.; **Burton W. Elgin**, of the Graham Bros. Corp.; **H. Happersberg**, of the Relay Motor Truck Corp.; **C. R. Rinehart**, of the Overman Cushion Tire Co.; and **Philip E. Whiting**, of the Walker Vehicle Co.

Announcement is made jointly by the Westinghouse Air Brake Co. and the Bendix Aviation Corp., of the formation of a new company to be known as the Bendix-Westinghuse Automotive Air-Brake Co., with the following S.A.E. Members forming part of the executive personnel of the new company: **Vincent Bendix**, president and director; **W. J. Buettner**, secretary and treasurer; **Victor W. Kliesrath**, director.

J. R. Archibald has recently taken over the management of Bothwell Motors, Ltd., of Regina, Saskatchewan, Can. His previous connection was as wholesale representative of G. E. Jacques, Ltd., also of Regina.

W. L. Ashby, now an aviation sales engineer with the Richfield Oil Co., in New York City, was until recently employed in a similar capacity by the Tide Water Oil Sales Corp., of Newark, N. J.

M. C. Baumann, who recently became consulting engineer for the Mercury Aircraft Corp. and Inland Aviation Co., of Kansas City, Kan., was previously chief engineer for the Butler Aircraft Corp., of Kansas City, Mo.

Frederick E. Brown, former president of the Penn Tractor Equipment Co., of Philadelphia, is the New York manager for the La Plant-Choate Mfg. Co., Inc., of Cedar Rapids, Iowa, and is in charge of exporting.

O. W. Brown, former sales manager of the Wisconsin Machinery & Mfg. Co., of Milwaukee, was recently elected vice-president of that company.

(*Continued on next left-hand page*)

KINGSTON - - -

To be successful-

Success can not be properly gauged in terms of dollars and cents, or in dividends paid to stockholders. The true success of any manufacturing organization may be judged from what it has contributed toward the growth and advancement of the industry.

The name of Kingston has ever been linked with major developments in the automotive field. ~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~

KINGSTON PRODUCTS CORPORATION

Manufacturers of Carburetors, Fuel Feeding Systems, Vacuum Tanks, Oil Pumps and Car Heaters

KOKOMO, INDIANA

Personal Notes of the Members

Continued

R. J. Burgh has accepted a position as sales engineer with the Griscom Russell Co., of New York City. His previous position was that of assistant in engineering at Brown University, in Providence, R. I.

W. O. Charles, assistant zone manager for the Olds Motor Works, has been transferred from the Denver zone to the Kansas City zone, with headquarters in Kansas City, Mo.

Thomas Cordery, until lately Vauxhall service specialist for the General Motors Australia Proprietary, Ltd., of Melbourne, has been transferred to London, England, and is now service-station manager and service-school superintendent there.

Capt. C. L. Ellis, U. S. A., assigned to plans and training, formerly with the 35th Infantry, Schofield Barracks, Hawaii, has been transferred to Fort Howard, Md.

Edward Dagner, who has been serving the Fageol Motor Sales Co. as manager of its Oakland, Cal., branch, has been transferred to the Oregon district, with headquarters in Portland.

Fred C. Goldsmith has recently joined the Hinderliter Tool Co., of Tulsa, Okla., as engineer. His former post was with the W-K-M Co., Inc., of Houston, Texas, as engineer and general superintendent.

Ralph R. Graichen has joined the firm of Gazley & La Sha, consulting engineers, City of Washington, in the capacity of aeronautic engineer. He was previously vice-president and chief engineer of the Metal Aircraft Corp., of Cincinnati.

Gustave Ingold, formerly service manager in the export department of the Auburn Automobile Co., is now supervisor of maintenance for that company for Europe, the British Isles and Northern Africa, with offices at Antwerp, Belgium.

Announcement made on p. 46 of the January JOURNAL to the effect that **Carl W. Johnson** has been promoted to the post of factory manager of the Cleveland Graphite Bronze Co., of Cleveland, was incorrect. Mr. Johnson's position with the above firm is that of director of sales.

Stephen Johnson, Jr., who is serving the Westinghouse Air Brake Co., was recently transferred from the Chicago office, where he was service engineer, to the factory at Pittsburgh, where he is acting as general engineer in the automotive brake division.

William H. Kelley, until lately production manager for Brewster & Co., of Long Island City, N. Y., has been appointed factory superintendent for the John H. McGowan Co., of Cincinnati.

S. L. Kerr has relinquished his connection as president and general manager of the Boise Motor Car Co., of Boise, Idaho, to become general manager for the Covey Motor Co., of Salt Lake City, Utah.

H. G. Lamker was recently elected secretary and treasurer of the Alloys Foundry Corp., of West Paterson, N. J. Previous to assuming this new post he was foundry superintendent for the Wright Aeronautical Corp., of Paterson, N. J.

Victor A. Larsen, who was until lately structural engineer, working in stress analysis, for the Commercial Aircraft Co. of America, in Bridgeport, Conn., is now a draftsman for the Sikorsky Aviation Corp., of the same city.

Guy S. Lennstrand is now in charge of sales for Scandinavia for the Chas. E. Bedaux, Ltd., in London, England. Previously he was supervisor of the Dodge Division of the Chrysler Corp. in London.

Word has been received here that **Georg H. Madelung** was recently appointed a professor at the Stuttgart Institute of Technology. Previous to this appointment, he was vice-president in charge of research at the German Insti-

(Concluded on next left-hand page)

These Sales are Safe because of LOCKHEED HYDRAULICS

One of the strongest, most outstanding and most stubborn facts in the automobile industry is this . . . *Tens of thousands of persons will have no car unless it is equipped with Lockheed Hydraulic Four Wheel Brakes* . . . Those potential sales are as safe, as valuable, to the manufacturer of cars equipped with Lockheed Hydraulics as money in the bank . . . To anyone who has ever driven a car equipped with them, the reasons for this pronounced preference for Lockheed Hydraulics are extremely plain . . . Lockheed-equipped cars *do* impart to the driver a *special* sense of safety and an added satisfaction and pleasure in driving . . . They accomplish these results because they are so effective—and so smooth, so even and so easy in their application . . . These attributes of Lockheed Hydraulic braking performance can be obtained, we believe, only through the hydraulic principle as employed in Lockheed Hydraulics . . . The tens of thousands of persons alluded to above clearly recognize the value of the hydraulic principle as applied to deceleration *through* Lockheed Hydraulics . . . They consider the value of that principle so great as to constitute reason sufficient, in and of itself, for restricting their selection of motor cars to that large and brilliant group equipped with Lockheed Hydraulics.

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Your hope of climbing sales figures depends not upon the blue prints of your engineers, but upon the opinion of the public after miles of service. Correct engineering and perfection of design drive the car out of the sales room. Only the perfect functioning of all important parts can keep it out of the shop.

In these days of high speeds through traffic the operation of the clutches assumes growing importance. B. C. A. Thrust and Angular Contact Radial Bearings are especially designed for this service. In the inspection room shown above they are rigidly inspected and tested to insure the proper operation of YOUR car in the ultimate trial of service on the road.

Bearings Company of America
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Detroit, Mich. Office: 1012 Ford Bldg.

Personal Notes of the Members

Concluded

tute for Aeronautical Research and a professor at the Charlottenburg Institute of Technology.

Walter Martins has recently become connected with the Thomas L. Gatke Co., of Chicago, where he is employed as a service engineer. Previous to making this connection he was the owner and general manager of the Automotive Service Co., also of Chicago.

C. N. Maurer has been appointed director of the highway sales division of the Heil Co., of Milwaukee. Mr. Maurer had for ten years been connected with the Wisconsin State Highway Commission.

J. B. McBride, a former sales-clinic instructor for the Ford Motor Co. of Canada, is now a special representative of the See & Duggan Motors, Ltd., of Toronto, Canada.

Hugo K. Moren has now joined the Westinghouse Electric & Mfg. Co., of South Philadelphia, Pa., to work on high-speed two-cycle Diesel engines.

Thorsten Y. Olsen has been elected president of the Tinius Olsen Testing Machinery Co., of Philadelphia, succeeding his father, who has retired from active participation in the affairs of the company after having been its active head for more than 50 years.

H. D. Parker recently relinquished his post as assistant to the vice-president in charge of sales with the Ramsey Chain Co., Inc., of Albany, N. Y., to join the Bailey-Burrus Mfg. Co., of Atlanta, Ga., as general manager.

G. Phillips, who has been employed as an experimental engineer by Lubrication Devices, Inc., of Battle Creek, Mich., has relinquished that position to enter the engineering department of E. C. Stearns & Co., of Syracuse, N. Y.

F. A. Quackenbush was recently made assistant superintendent in charge of motorcoach operation with the Cedar Rapids & Iowa City Railway. His former position was that of service engineer with the General Motors Truck Co., of Pontiac, Mich.

Carl F. Rauen, until lately assistant aeronautical engineer, in the Materiel Division, Wright Field, Dayton, Ohio, is now connected with the Detroit Gear & Machine Co., also of Dayton, in the capacity of engineer.

Ralph E. Schlenker recently became inspector of castings for the Allen, Sherman Hoff Co., of Hamburg, Pa. He was formerly a draftsman with the Parish Pressed Steel Co., of Reading, Pa.

William Schroeder lately severed his connection with the Western Electric Co., of Kearny, N. J., for which he was material-handling division department chief, to join the Mercury Mfg. Co., of Chicago, as chief engineer.

L. F. Serrick recently assumed the duties of secretary and sales manager for the Napoleon Products Co., of Napoleon, Ohio. Previous to making this connection he was secretary and general manager for the Defiance Automatic Screw Co., of Defiance, Ohio.

Clifford W. Smith, formerly a minor layout draftsman for Dietrich, Inc., of Detroit, is now a body-layout draftsman for the H. H. Franklin Mfg. Co., of Syracuse, N. Y.

W. Taylor has resigned as chief engineer for the Scripps Motor Co., of Detroit, to become a marine engineer for the Lycoming Mfg. Co., of Williamsport, Pa.

William B. Todd, manager of sales in the cold-finished department of the Jones & Laughlin Steel Corp., of Pittsburgh, has been appointed assistant general manager of sales for that company.

W. B. Wachtler returned recently from abroad, where he was assistant managing director of General Motors, G.M.B.H., of Berlin, Germany. He is now assistant general sales manager of the General Motors Export Co., of New York City.

Ronald J. Waterbury, who recently became a body research engineer for the Chevrolet Motor Co., of Detroit, Mich., was previously assistant general manager for the Central Mfg. Co., of Connersville, Ind.